# quarterly analysis review

# 17.3

## 3Q 2017


| | |
|---|---|
| vto | kelly fleming, rachael nealer, jake ward |
| anl | josh auld, amgad elgowainy, dave gohlke, jarod kelly, eric rask, aymeric rousseau, tom stephens, michael wang, joann zhou |
| energetics | alicia birky |
| lbnl | mark delucchi, anand gopal, sam saxena, margaret taylor |
| ornl | stacy davis, zhenhong lin |
| nrel | aaron brooker, jeff gonder, marc melaina, mark singer, eric wood |
| snl | brandon heimer, becky levinson, nesty ray torres, todd west |
| sra/sentech | russ campbell, karen sikes |


16 october 2017

# topics

1 energy markets

automotive markets

technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar

# outline

# 1 energy markets

## vehicle fuels

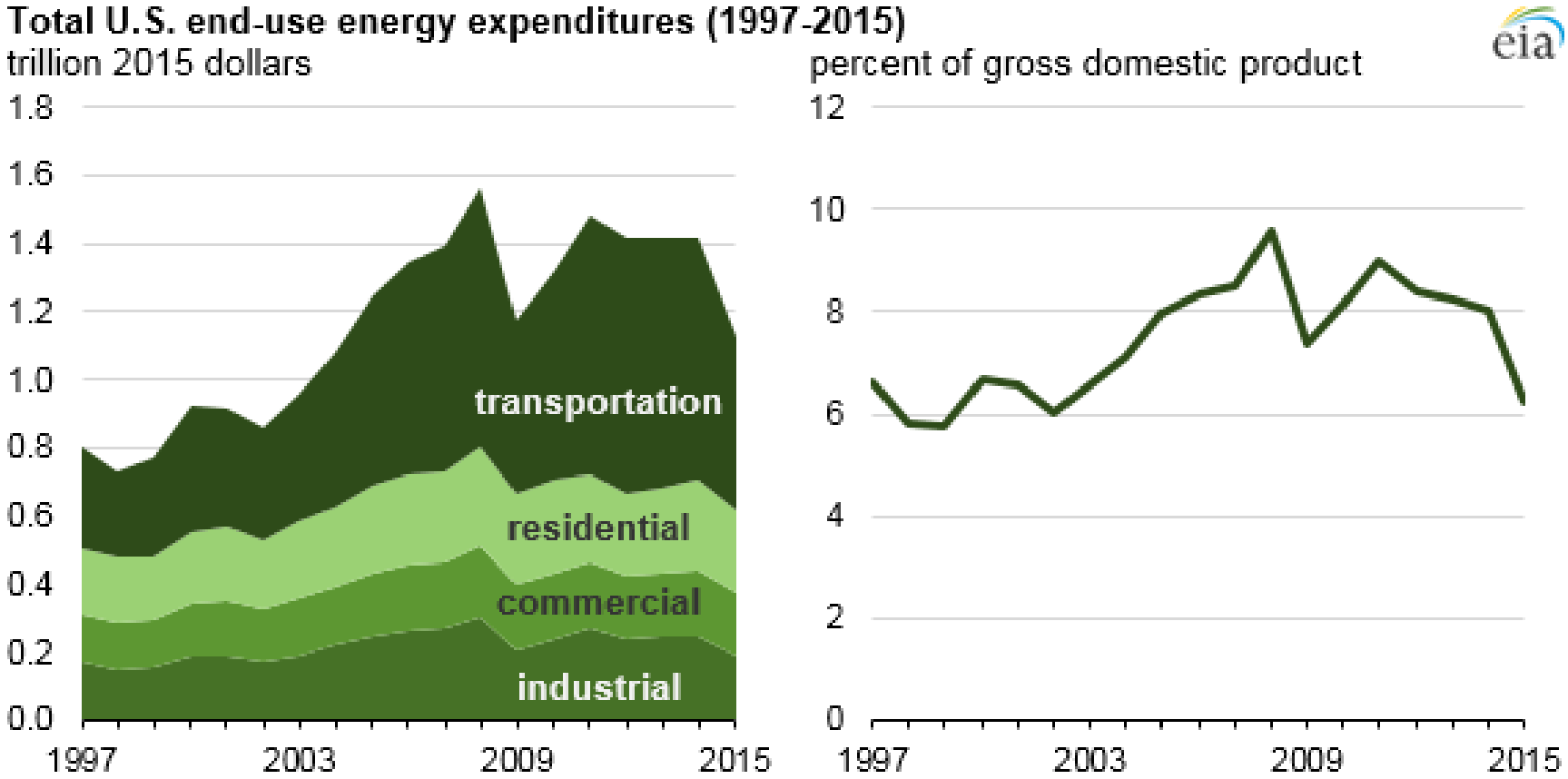
- EIA: 45% of total U.S. energy expenditures in 2015 were in the transportation sector
- EIA: U.S. household spending for gasoline is expected to remain below $2,000 in 2017
- EIA, FOTW: Gasoline prices have been relatively low and stable since 2015, lower than during 1930s and 1980s peaks after accounting for inflation
- Bloomberg: Premium gasoline sales have grown since 2008, while midgrade sales have declined

## energy markets/production

- FOTW: The price of a barrel of crude oil in 2016 was the lowest since 2003
- FOTW: Transportation is responsible for over 70% of domestic petroleum consumption in the U.S.
- EIA: Gasoline production from U.S. refineries near record levels for most of 2017, though Hurricane Harvey disrupted Gulf Coast oil supply
- EIA: U.S. ethanol production at record levels in 2017

# energy prices

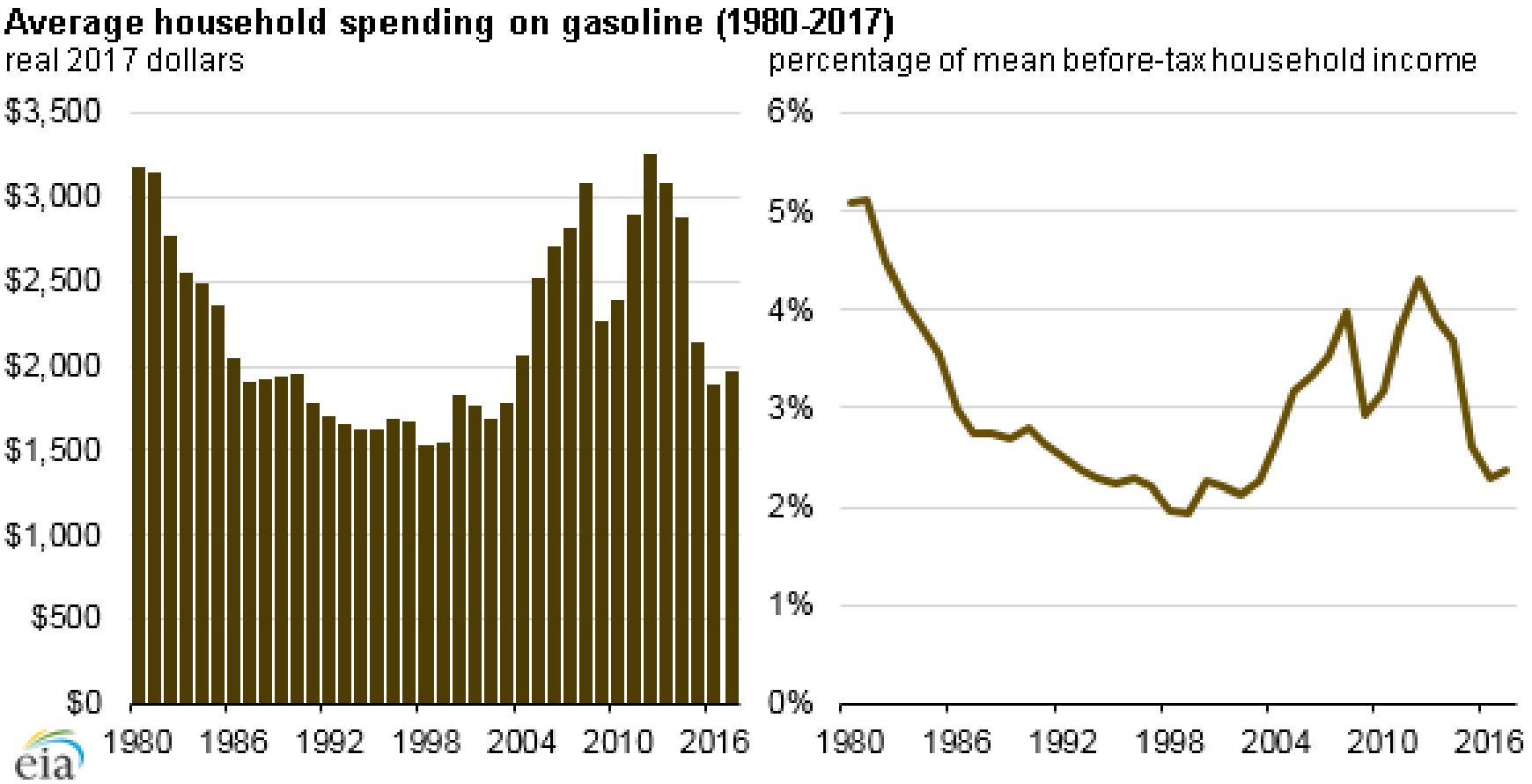
## EIA: 45% of total U.S. energy expenditures in 2015 were in the transportation sector – #1 in 47 states




Source: https://www.eia.gov/todayinenergy/detail.php?id=32432

# energy prices

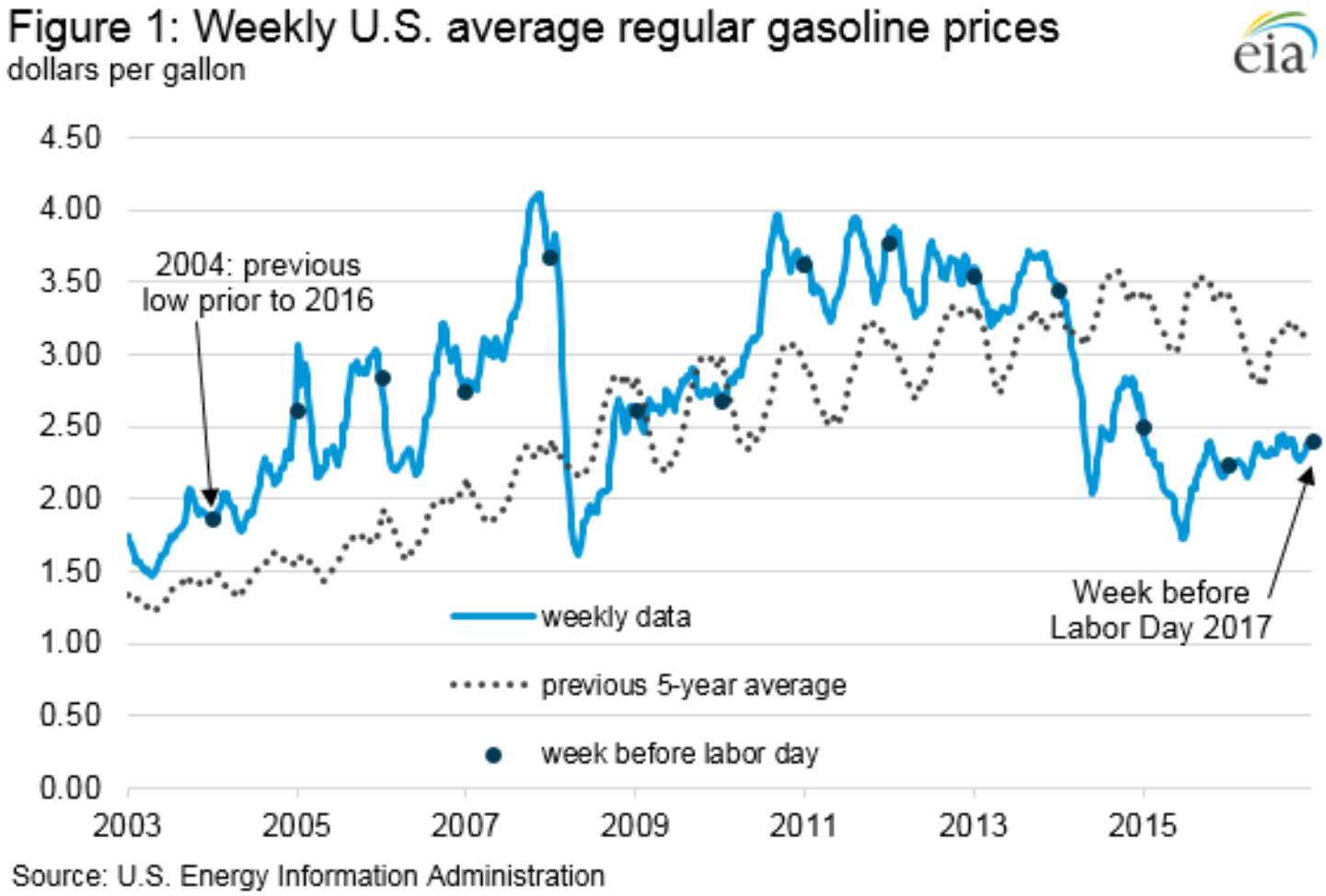
## EIA: U.S. household spending for gasoline is expected to remain below $2,000 in 2017




Source: https://www.eia.gov/todayinenergy/detail.php?id=33232

# gasoline prices

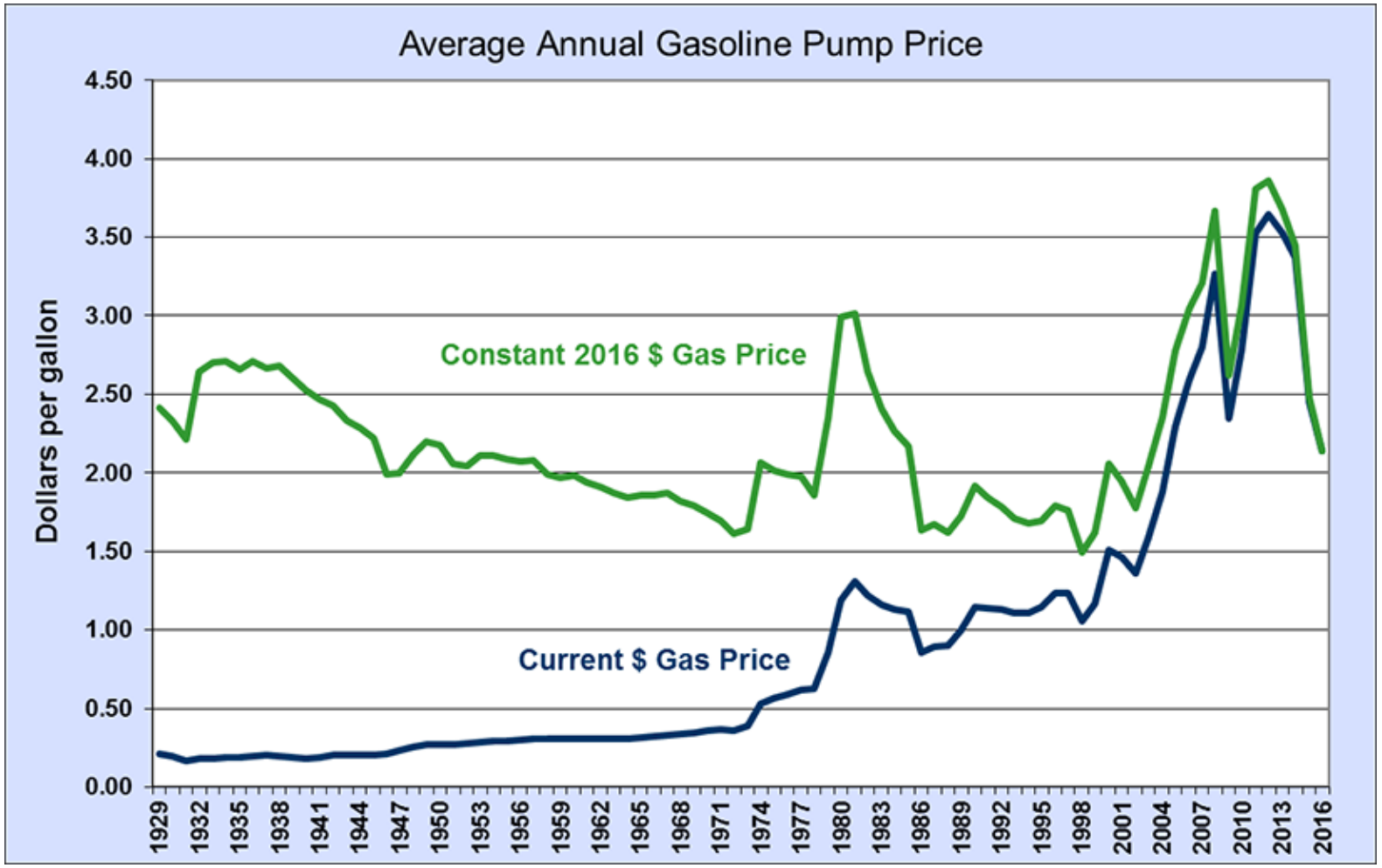
## EIA: Gasoline prices have been relatively low and stable since 2015




Source: https://www.eia.gov/petroleum/weekly/archive/2017/170830/includes/analysis_print.php

# gasoline prices

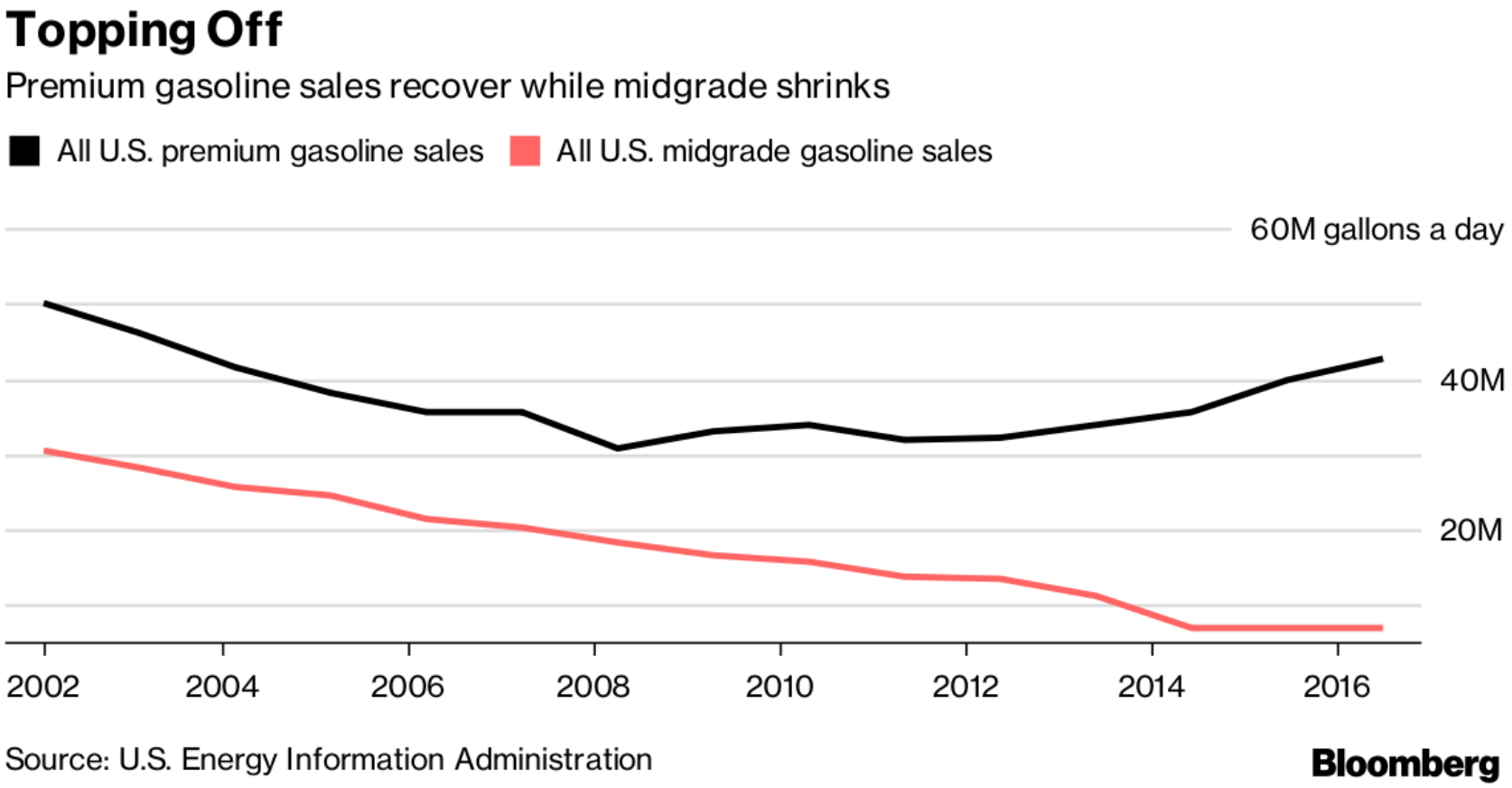
## FOTW: Gasoline prices are currently lower than during 1930s and 1980s after accounting for inflation




Source: https://energy.gov/eere/vehicles/articles/fact-985-july-10-2017-average-historical-annual-gasoline-pump-price-1929-2016

# gasoline prices

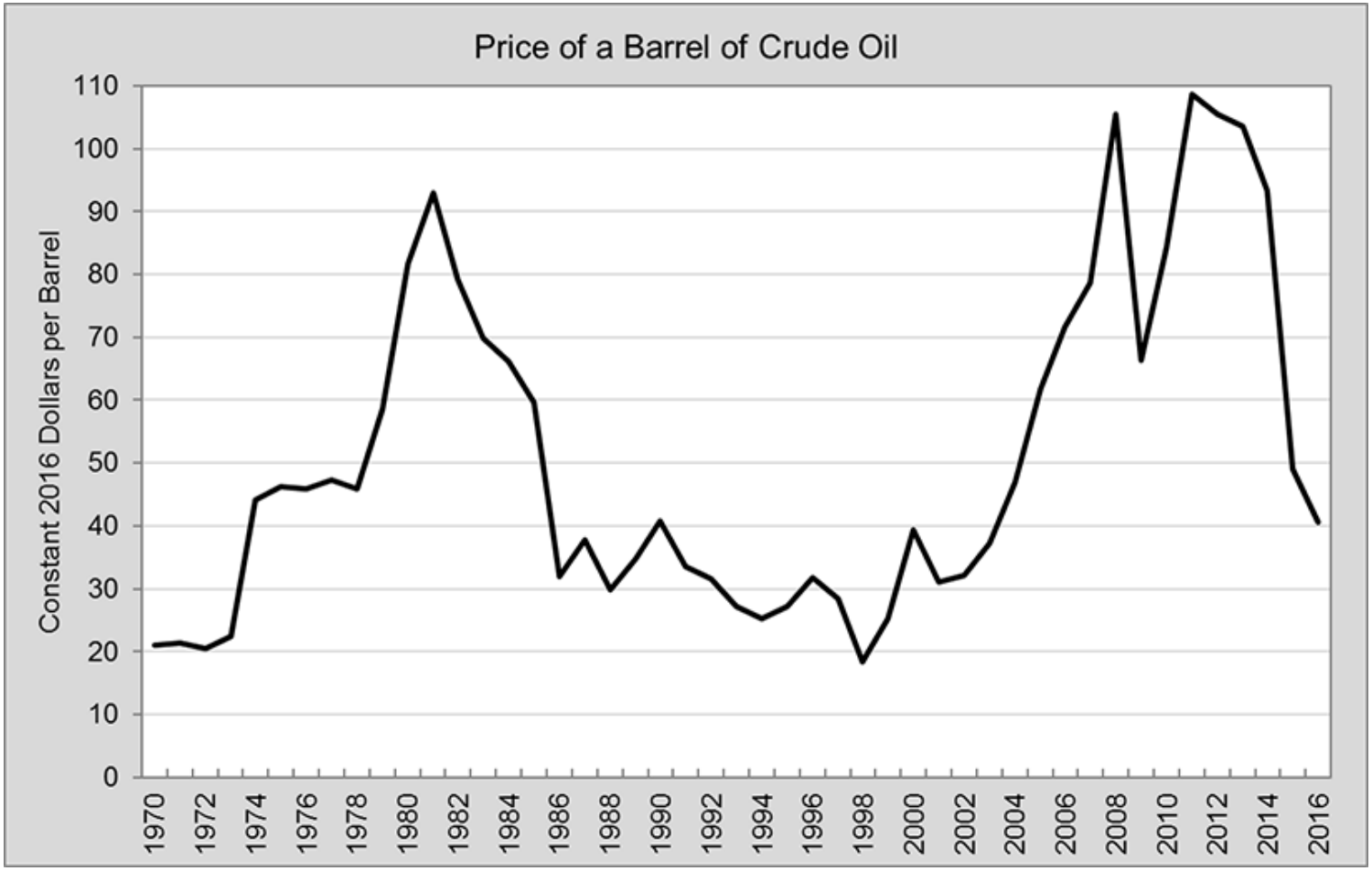
## Bloomberg: Premium gasoline sales have grown since 2008, while midgrade sales have declined




Source: https://www.bloomberg.com/news/articles/2017-10-03/avoiding-the-knock-drivers-push-premium-gasoline-prices-higher

# oil markets

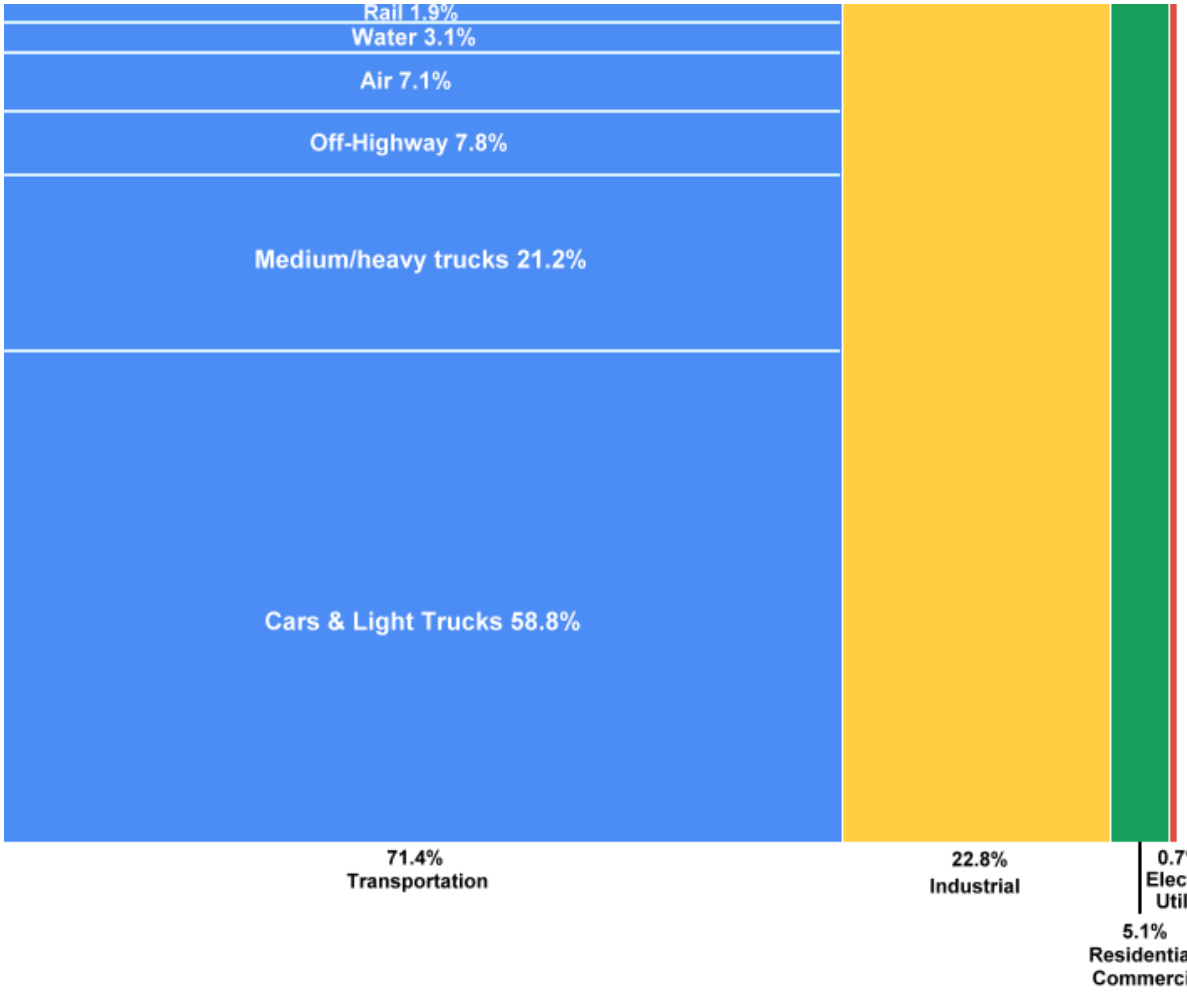
## FOTW: The price of a barrel of crude oil in 2016 was the lowest since 2003




Source: https://energy.gov/eere/vehicles/articles/fact-986-july-17-2017-price-barrel-crude-oil-2016-was-lowest-2003

# oil markets

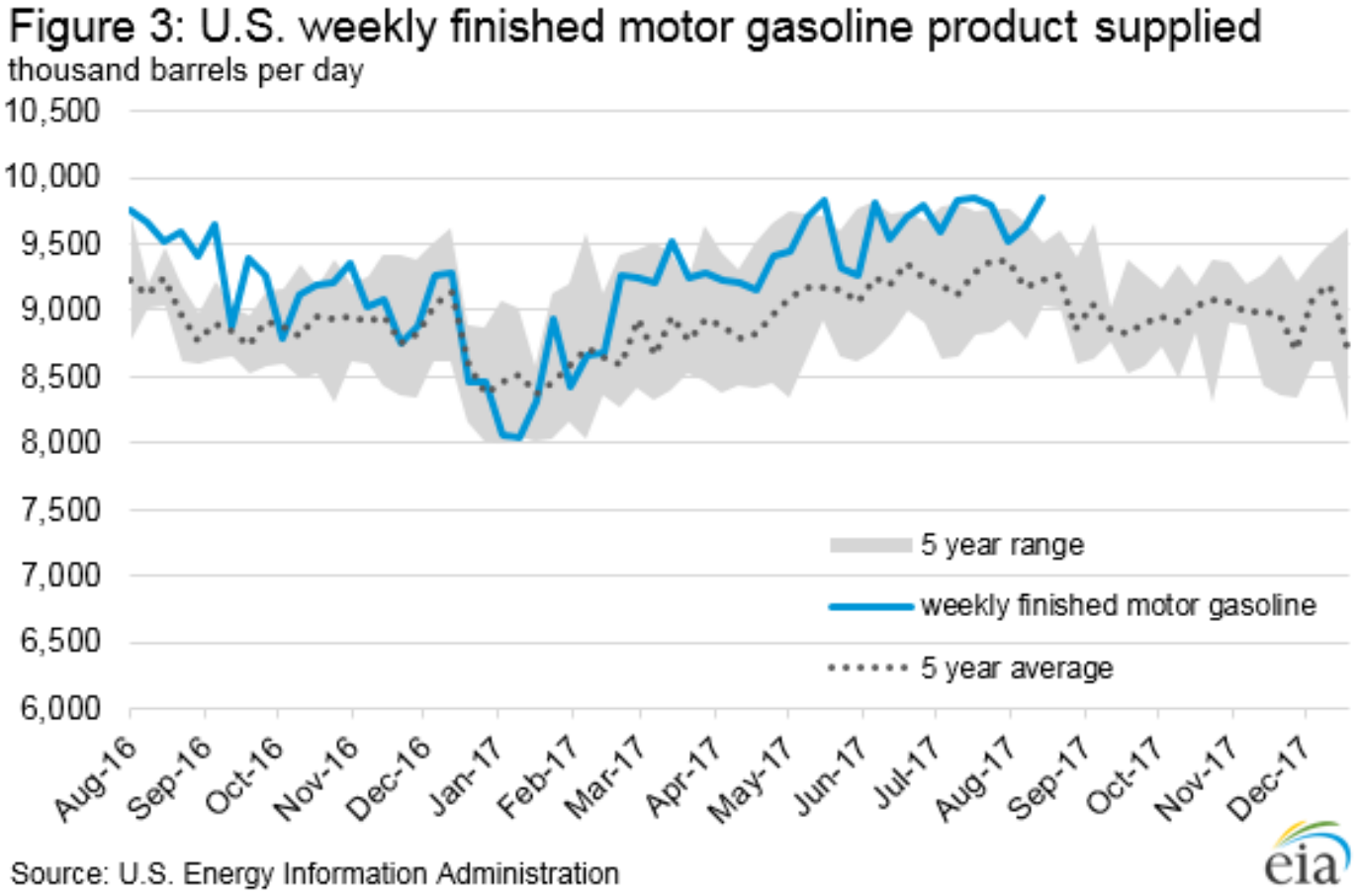
## FOTW: Transportation is responsible for over 70% of domestic petroleum consumption in the U.S.




Source: https://energy.gov/eere/vehicles/articles/fact-996-september-25-2017-transportation-accounts-nearly-three-quarters

# oil markets

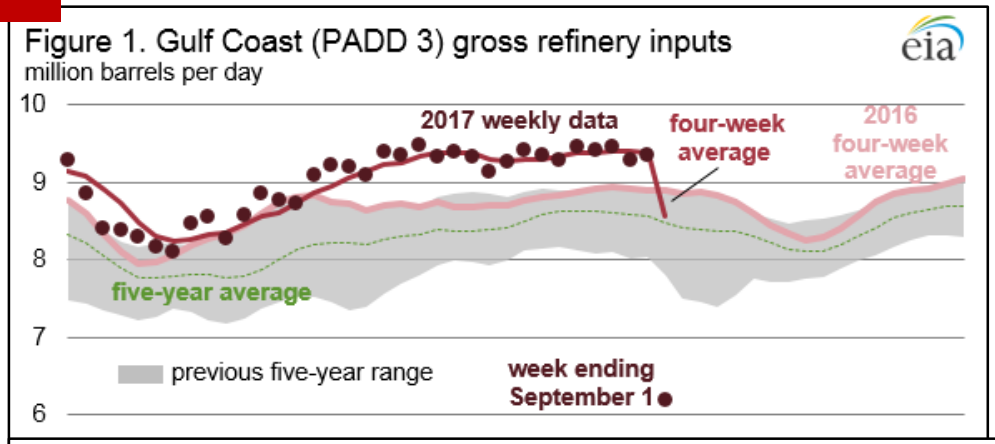
## EIA: Gasoline production from U.S. refineries has been near record levels for most of 2017

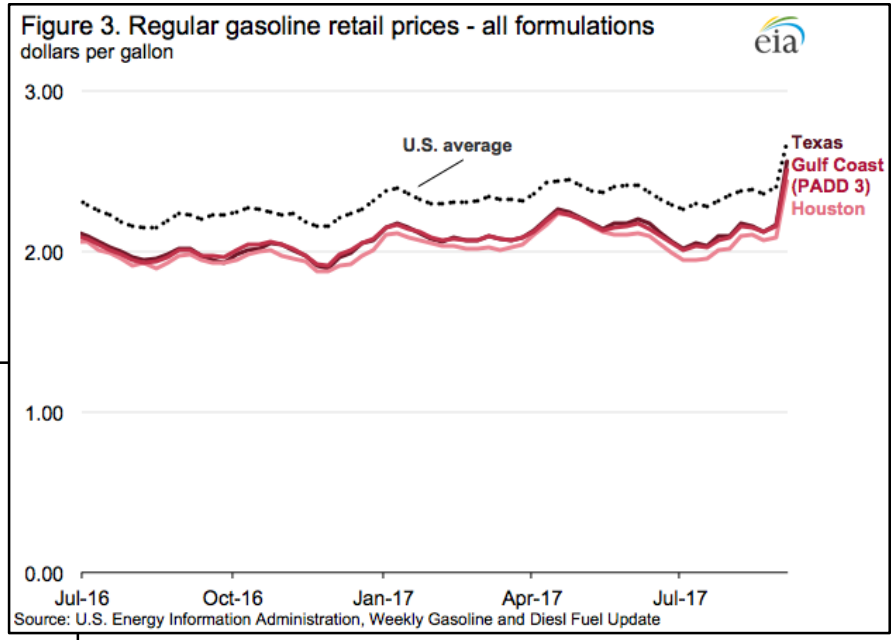


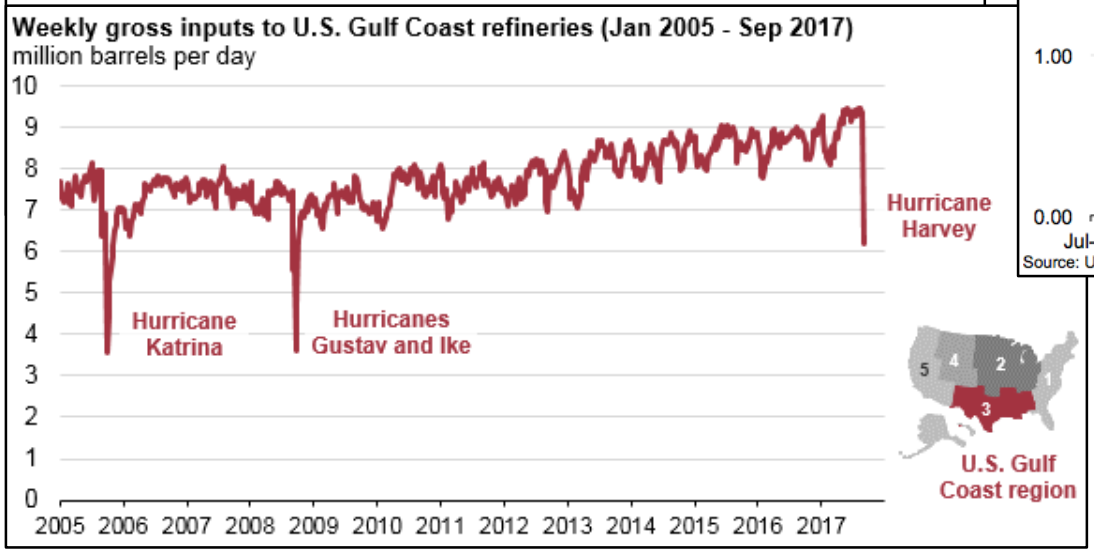

Source: https://www.eia.gov/petroleum/weekly/archive/2017/170830/includes/analysis_print.php

# oil markets

## EIA: Hurricane Harvey disrupted Gulf Coast refineries, infrastructure, and supply chains



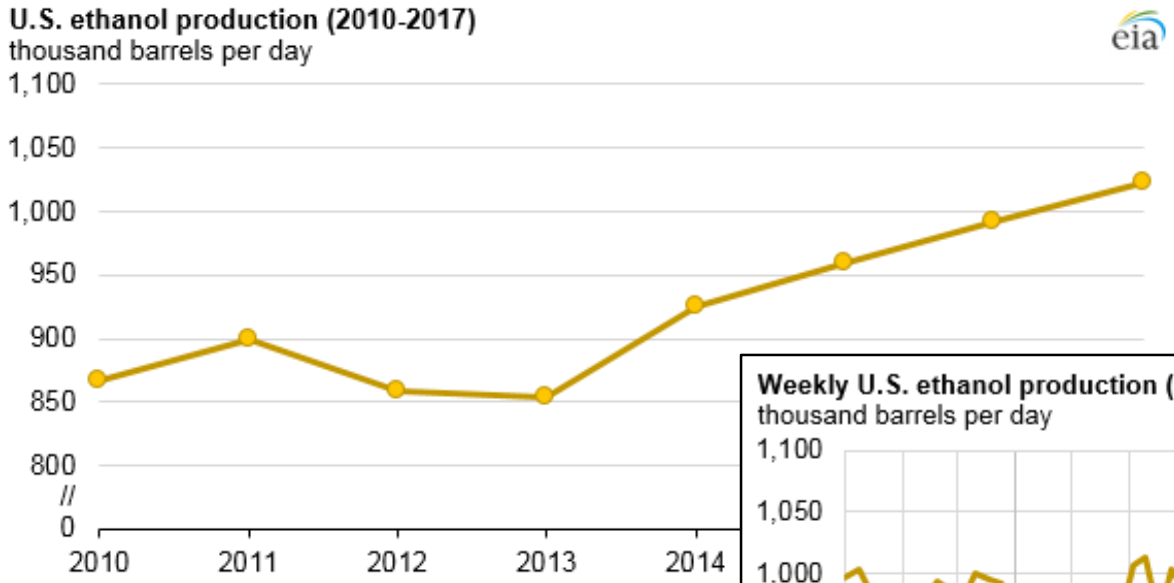



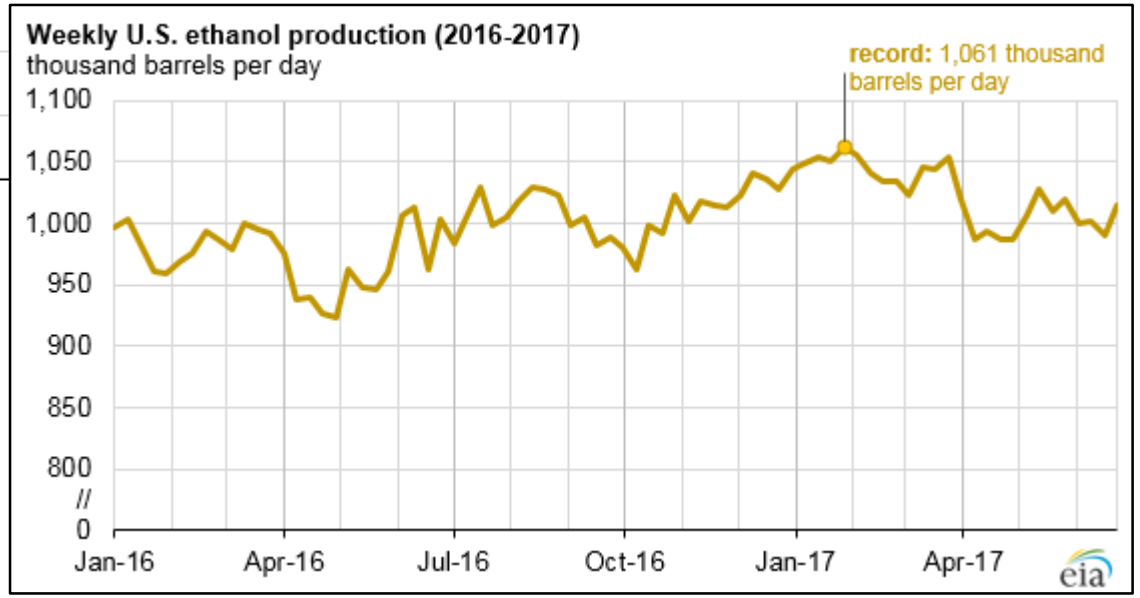




Sources: https://www.eia.gov/petroleum/weekly/archive/2017/170908/includes/analysis_print.php and https://www.eia.gov/todayinenergy/detail.php?id=32852

# biofuels

## EIA: U.S. ethanol production at record levels in 2017




Source: https://www.eia.gov/todayinenergy/detail.php?id=32152

# topics

2

energy markets

**automotive markets**

technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar

# outline

# 2 automotive markets

## LDV market

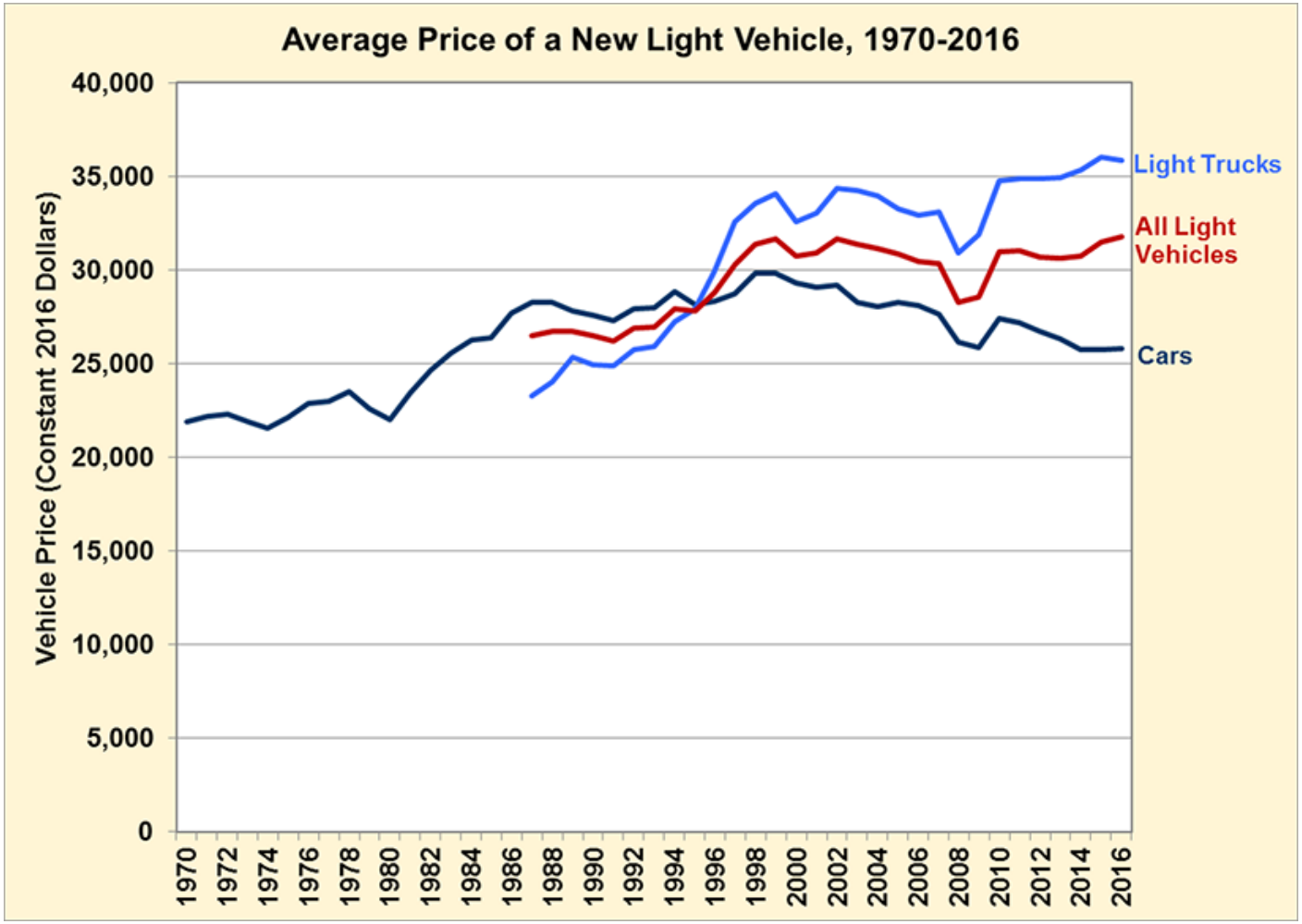
> FOTW: The average price of a new light vehicle was nearly $32,000 in 2016
> FOTW: The most common price point for light vehicles sold in 2016 was $27,000
> FOTW: The average age of cars and light trucks was almost twelve years old in 2016

## PEV market

> Morgan Stanley via Elektrek: PEV sales may pass ICE sales worldwide by 2040
> Morgan Stanley: More BEVs will be on the roads than ICE by 2050
> BNEF: 54% of new car sales and 33% of global car fleet will be electric by 2040
> Bloomberg: OPEC quintupled its forecast for sales of PEVs over last year
> Wood Mackenzie & GTM: Reduced battery prices can drive major growth in worldwide EV sales
> ING: 100% of European LDV sales will be PEVs by 2035 after 3 product cycles

# LDV market

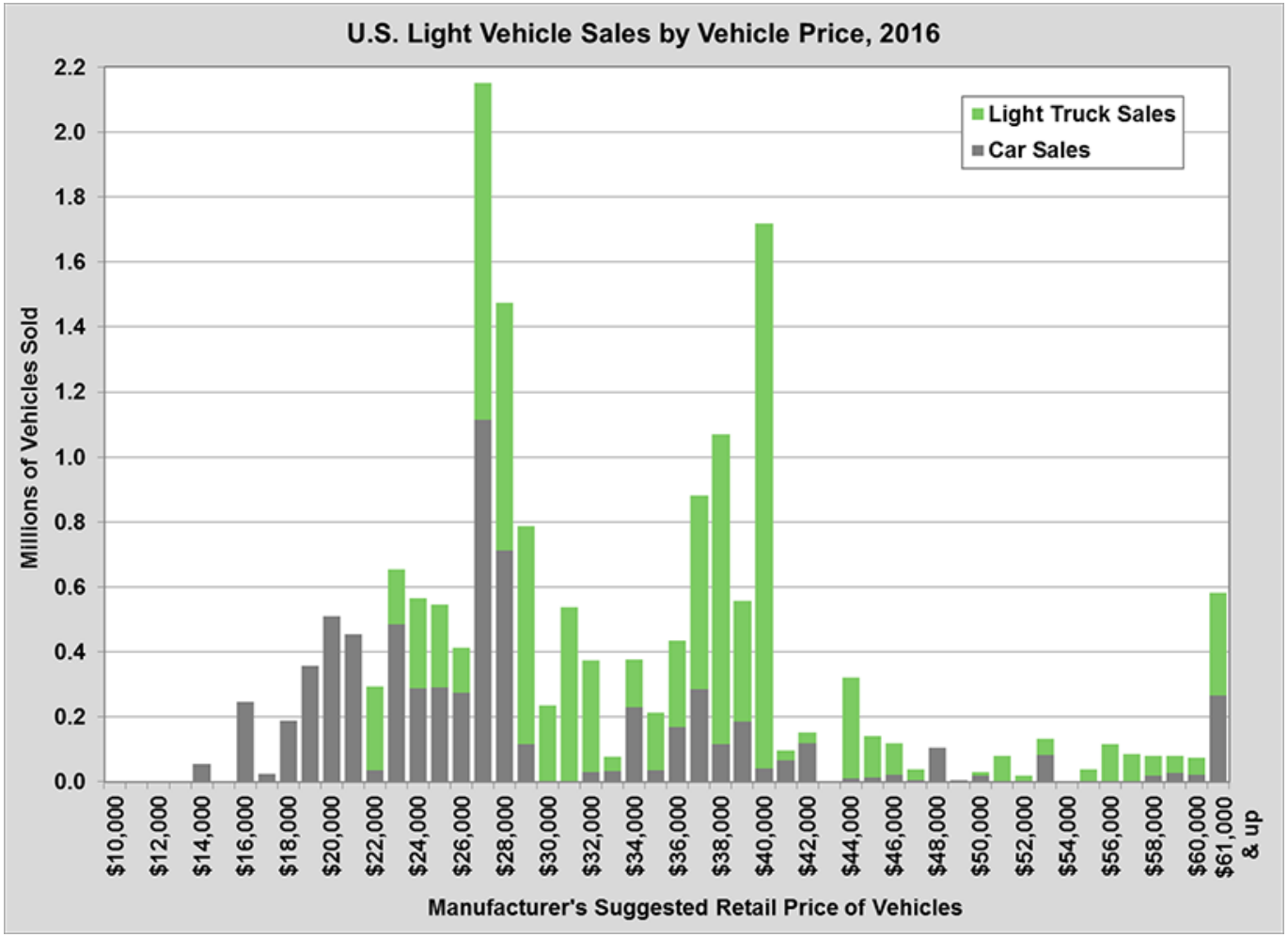
## FOTW: The average price of a new light vehicle was nearly $32,000 in 2016




Source: https://energy.gov/eere/vehicles/articles/fact-988-july-31-2017-average-price-new-light-vehicle-was-nearly-32000-2016

# LDV market

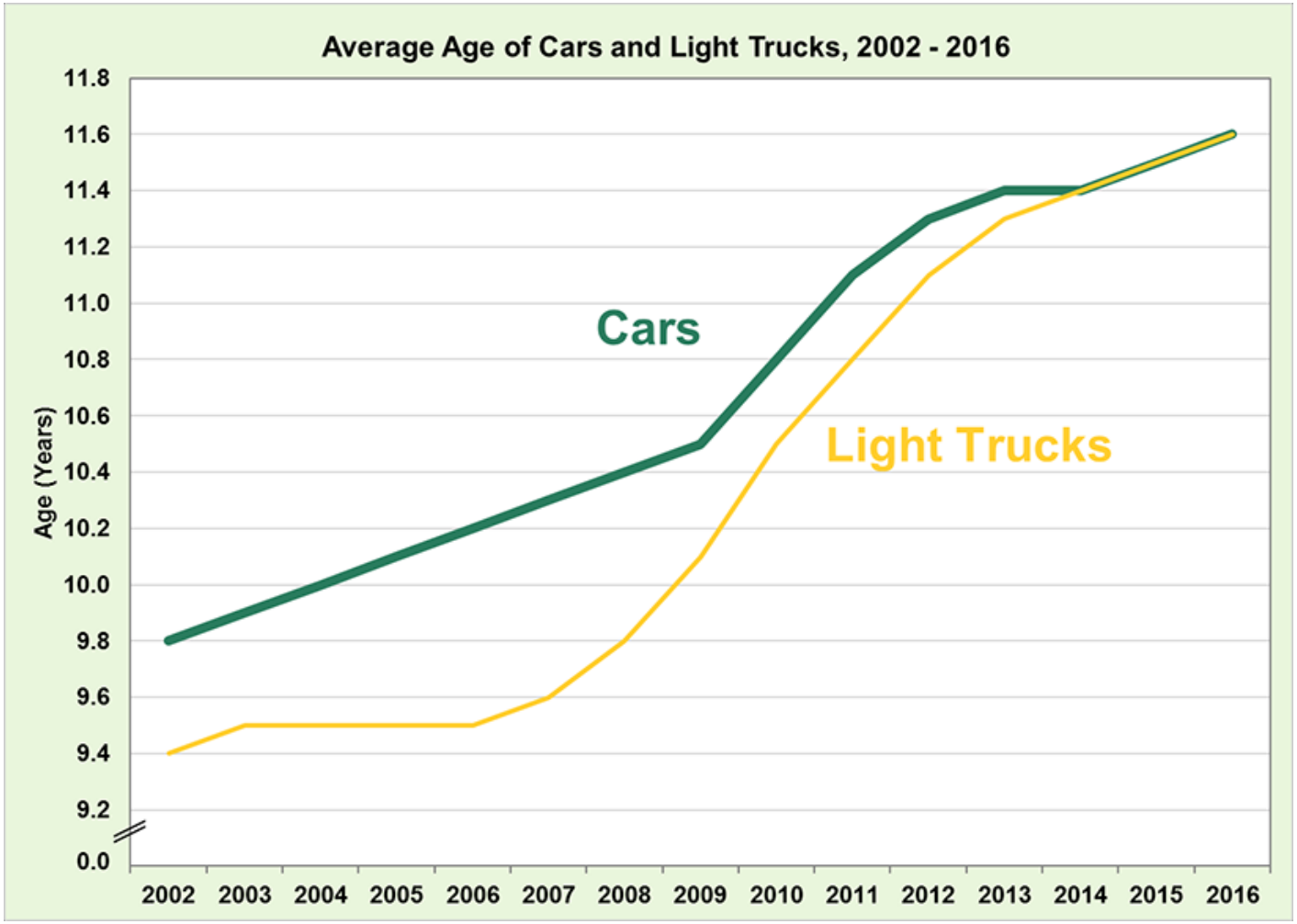
## FOTW: The most common price point for light vehicles sold in 2016 was $27,000




Source: https://energy.gov/eere/vehicles/articles/fact-989-august-7-2017-most-common-price-point-light-vehicles-sold-2016-was

# LDV market

## FOTW: The average age of cars and light trucks was almost twelve years old in 2016

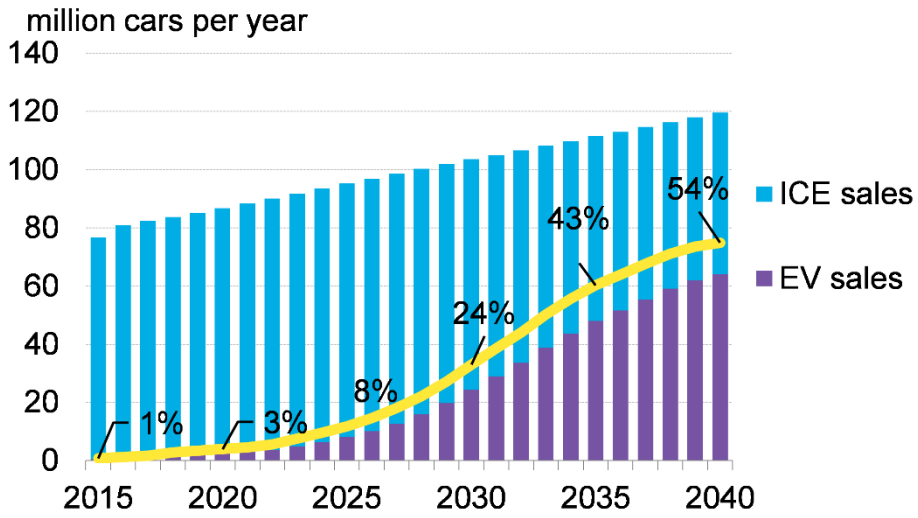



Source: https://energy.gov/eere/vehicles/articles/fact-997-october-2-2017-average-age-cars-and-light-trucks-was-almost-12-years

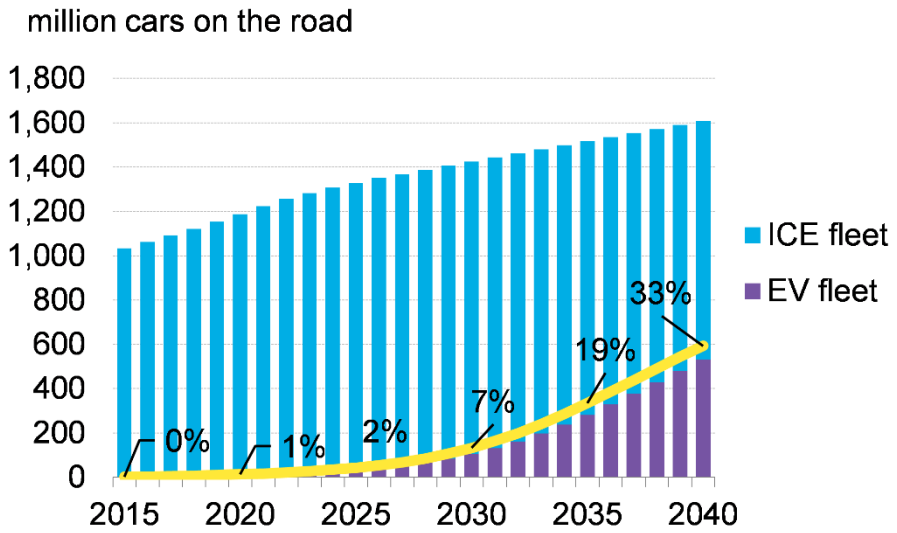
# PEV market

## BNEF: 54% of new car sales and 33% of global car fleet will be electric by 2040

Annual global light-duty vehicle sales



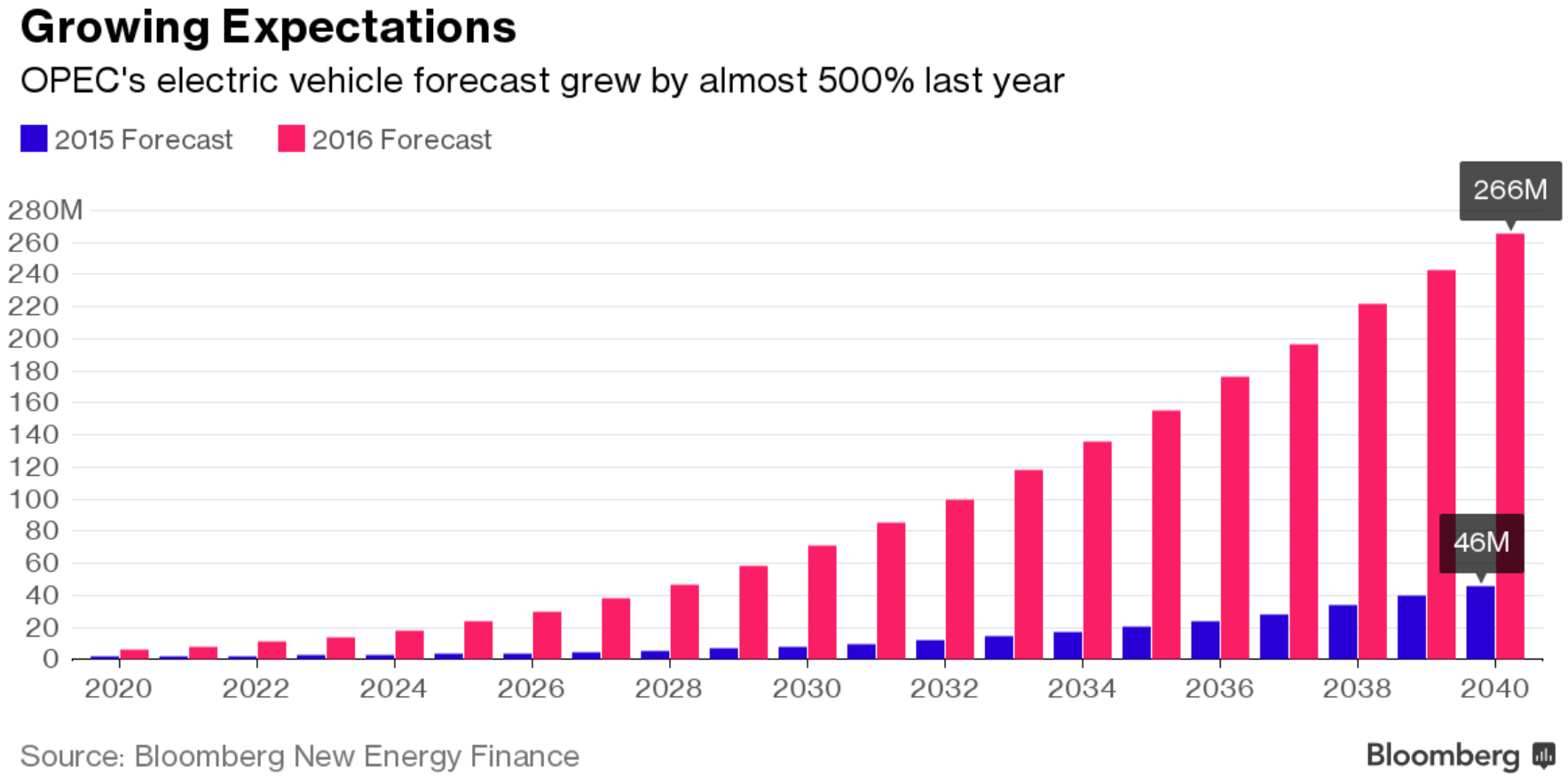

Global light-duty vehicle fleet




Source: https://about.bnef.com/blog/electric-vehicles-accelerate-54-new-car-sales-2040/

# PEV market

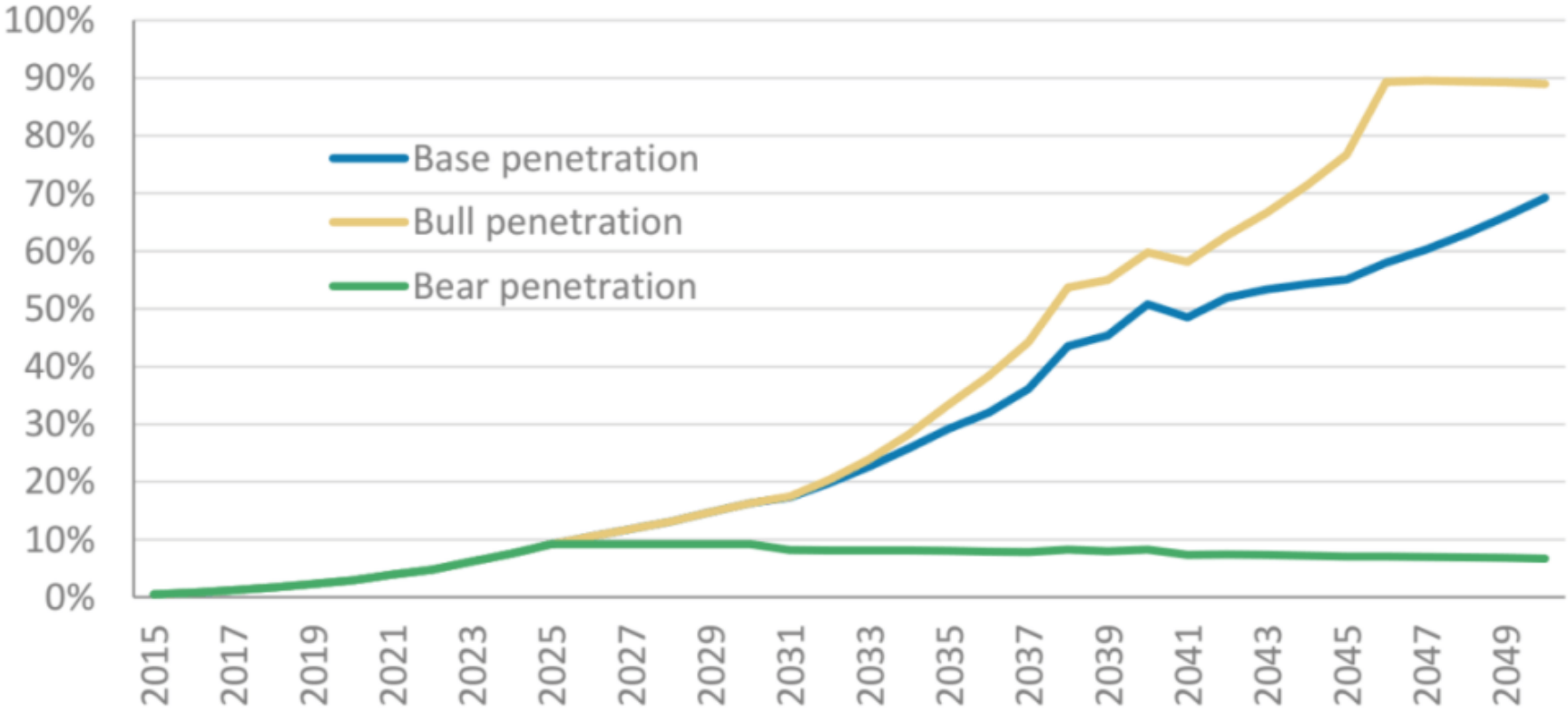
## Bloomberg: OPEC quintupled its forecast for sales of PEVs over last year




Source: https://www.bloomberg.com/news/articles/2017-07-14/big-oil-just-woke-up-to-the-threat-of-rising-electric-car-demand

# PEV market

## Morgan Stanley via Elektrek: PEV sales may pass ICE sales worldwide by 2040



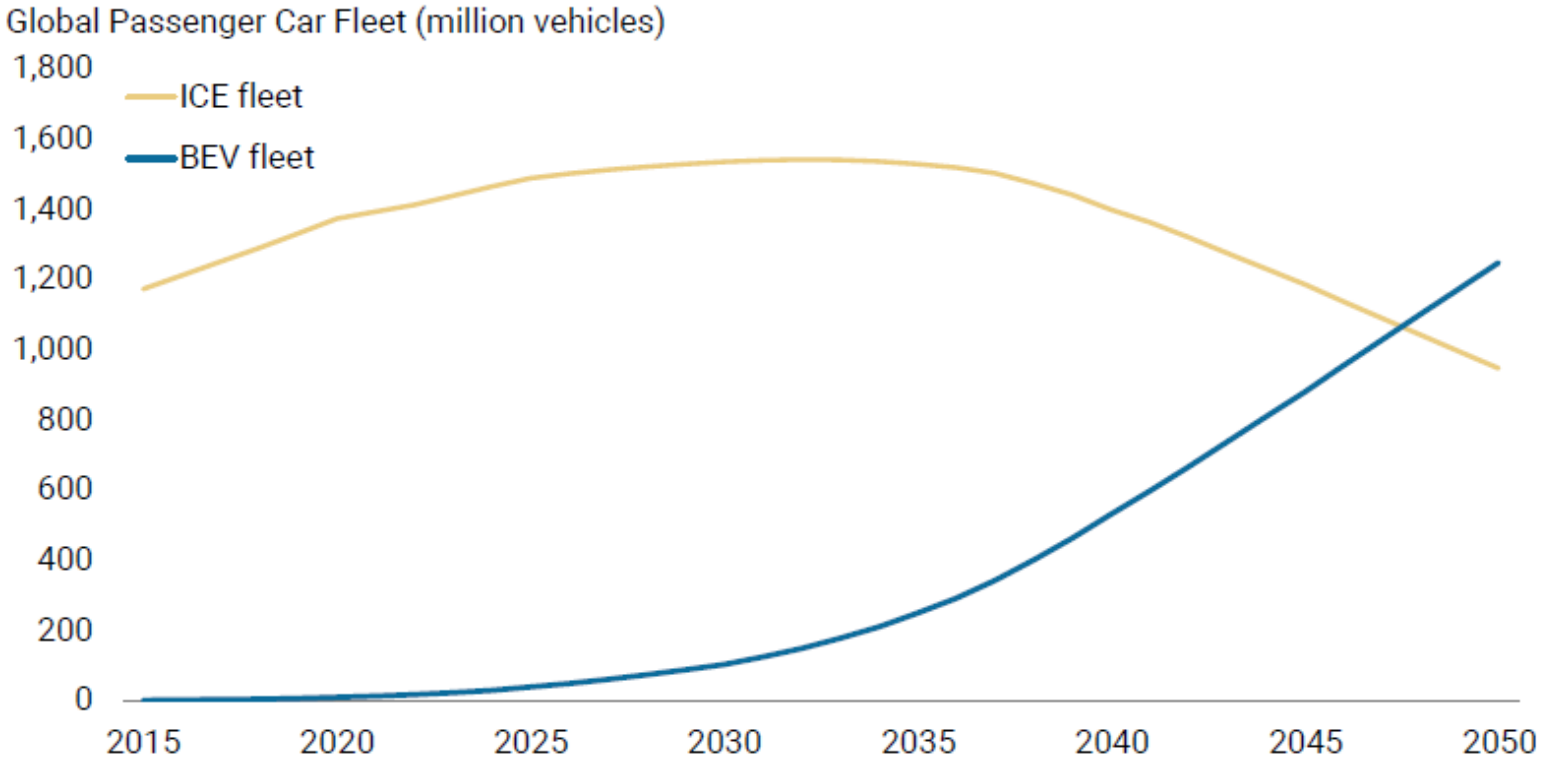

Source: Ward's, ACEA, CAAM, Morgan Stanley Research estimates (from 2017 onwards). Note: Chart shows new battery EVs as a % of total new car sales.

Source: https://electrek.co/2017/05/05/electric-vehicle-sales-vs-gas-2040/

# PEV market

## Morgan Stanley: More BEVs will be on the roads than ICE by 2050

We forecast a BEV fleet of one billion by 2050, while the ICE fleet grows until 2030 and only starts to fall sharply after 2035

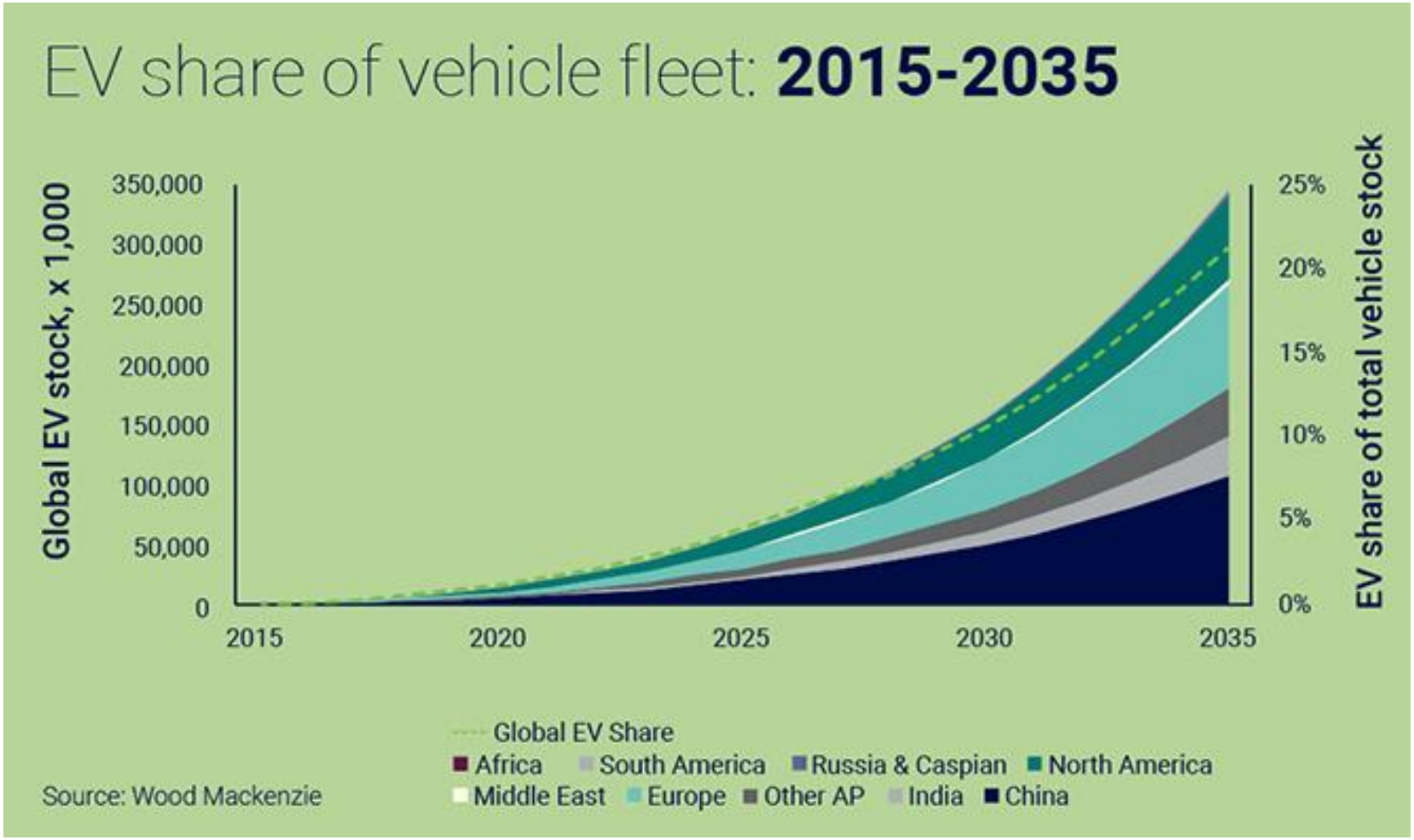



Source Morgan Stanley Research estimates

Source: https://www.docdroid.net/A5uNOPX/on-the-charge.pdf

# PEV market

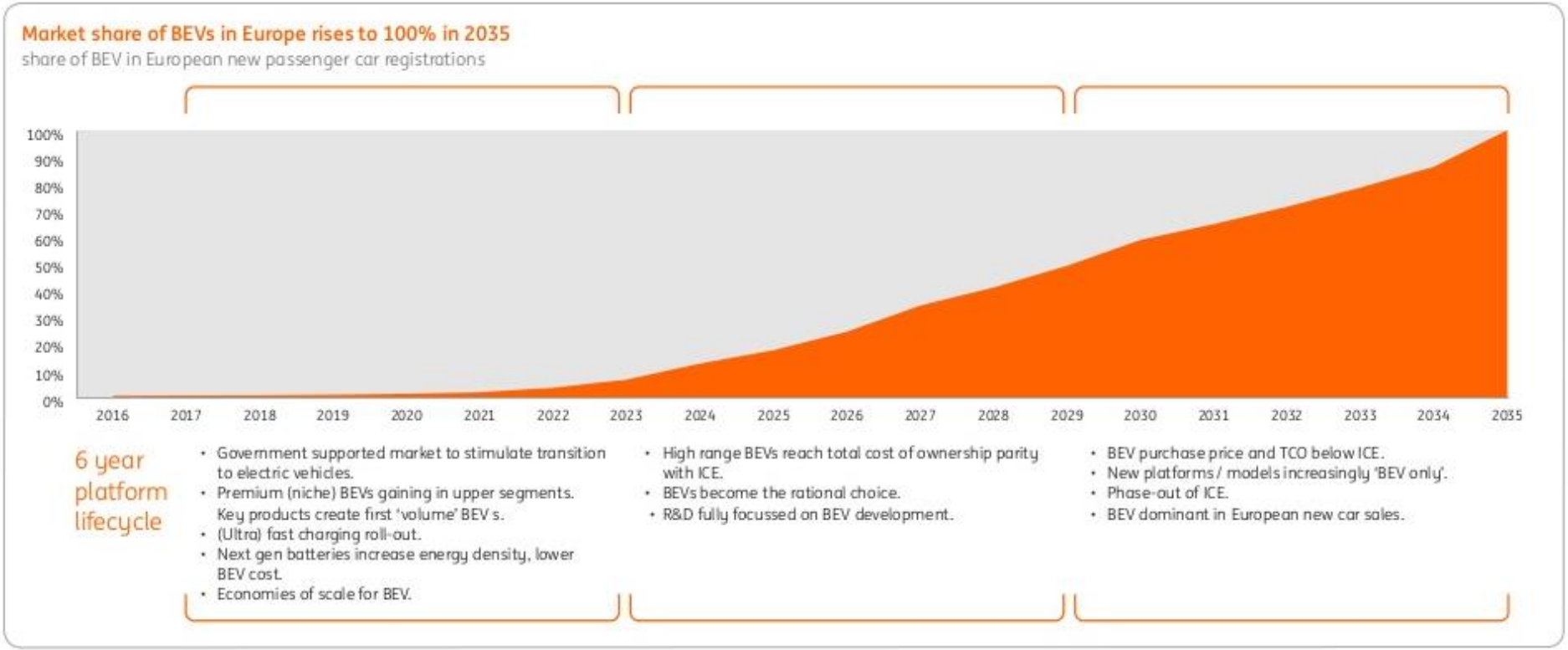
## Wood Mackenzie & GTM: Reduced battery prices can drive major growth in worldwide EV sales




Source: https://www.woodmac.com/analysis/future-of-renewables-radical-disruption

# PEV market

## ING: 100% of European LDV sales will be PEVs by 2035 after 3 product cycles




Source: https://www.ing.com/Newsroom/All-news/Electric-cars-will-take-over-threatening-European-car-industry.htm

## topics

energy markets

automotive markets

3 technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar

# outline

# 3 technologies studies

## Technology cost

> ICCT: Manufacturing cost to make diesel LDVs more efficient
> CMU/Berkeley/UM: Slower acceleration can reduce OEM costs
> Alix: Cost of EV motors could fall 20% by 2025
> Alix: Cost of AV systems should drop 78% by 2025

## EV Charging

> NREL: 400 corridor DCFC stations can cover the continental US
> Navigant/Fuels Institute: Electricity consumption to grow 32-37% / year

## HDV Energy Use

> IEA: Efficiency gains expected to fully counter increased demand for HDV through 2050 in developed countries, but not developing countries

## CAVs

> Axios: People at fault in majority of car accidents involving AVs
> UM: Sensors for CAVs can supplement and improve upon human vision

# technology cost

## ICCT: Manufacturing cost to make diesel LDVs more efficient expected to be under $100 / % fuel reduction

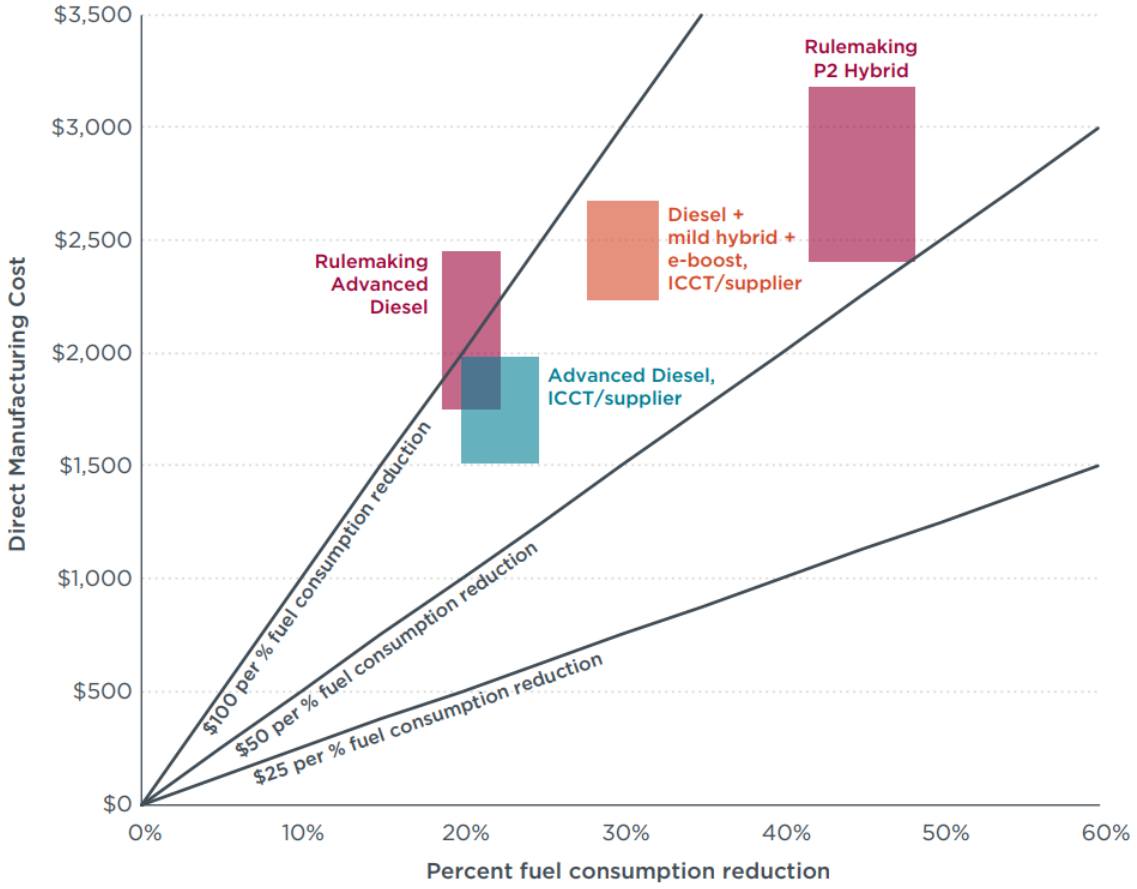


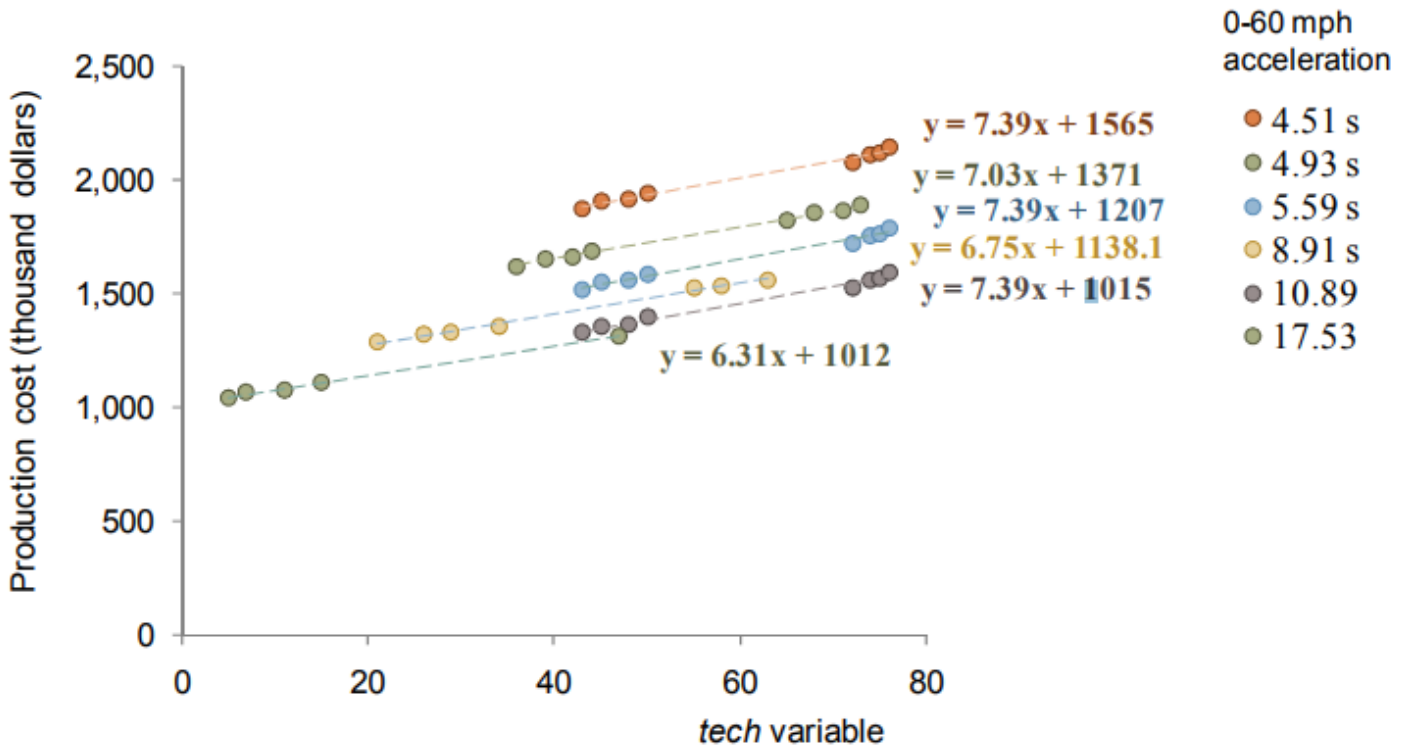

**Figure 4:** Comparison of rulemaking and ICCT/supplier estimates of direct manufacturing cost per percent fuel consumption reduction in 2025.

Source: http://theicct.org/sites/default/files/publications/Diesel-Engines_ICCT-Working-Paper_10072017_vF.pdf

# technology cost

## CMU/Berkeley/UM: Producing vehicles with slower acceleration can reduce OEM production costs

Figure S5: Relationship of ordered technology feature combinations to production cost conditional on 0-60 mph acceleration time

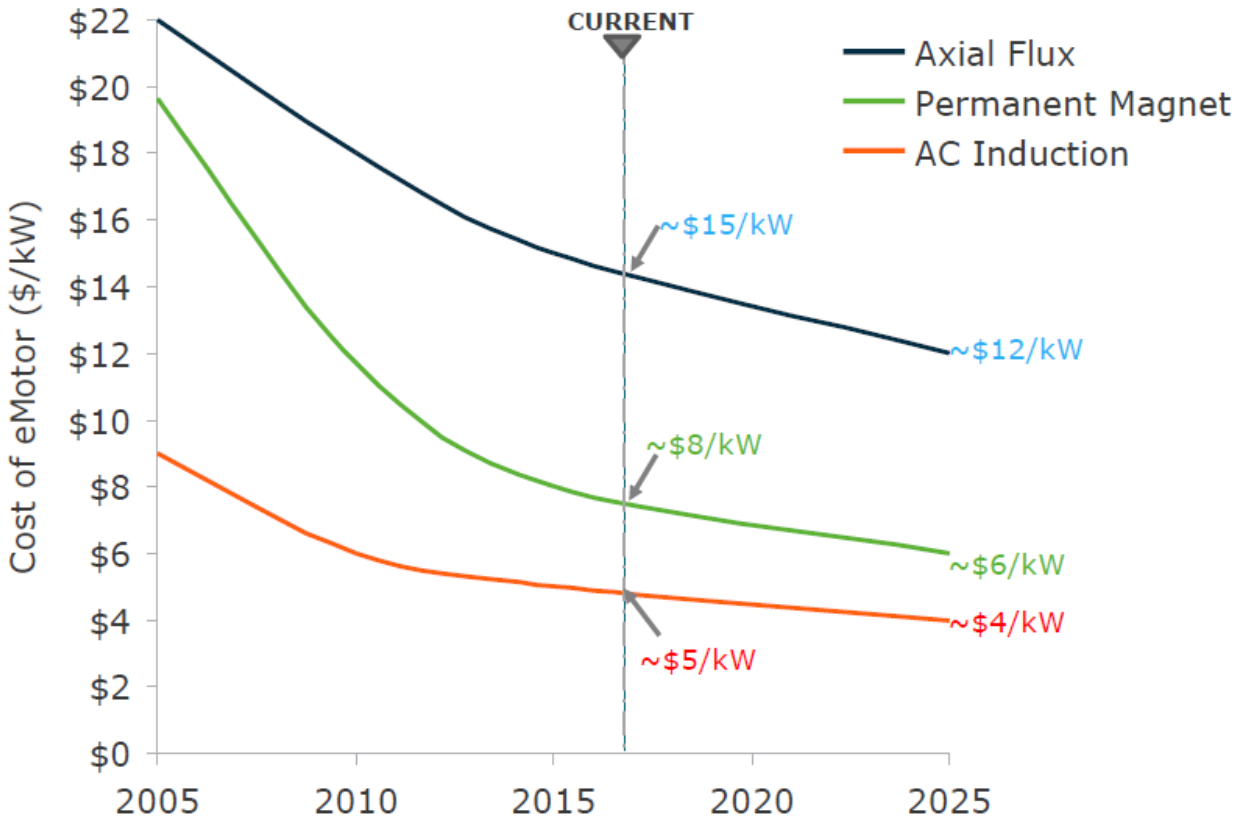



Source: http://pubs.acs.org/doi/abs/10.1021/acs.est.7b03743

# technology cost

## Alix: Cost of EV motors could fall 20% by 2025

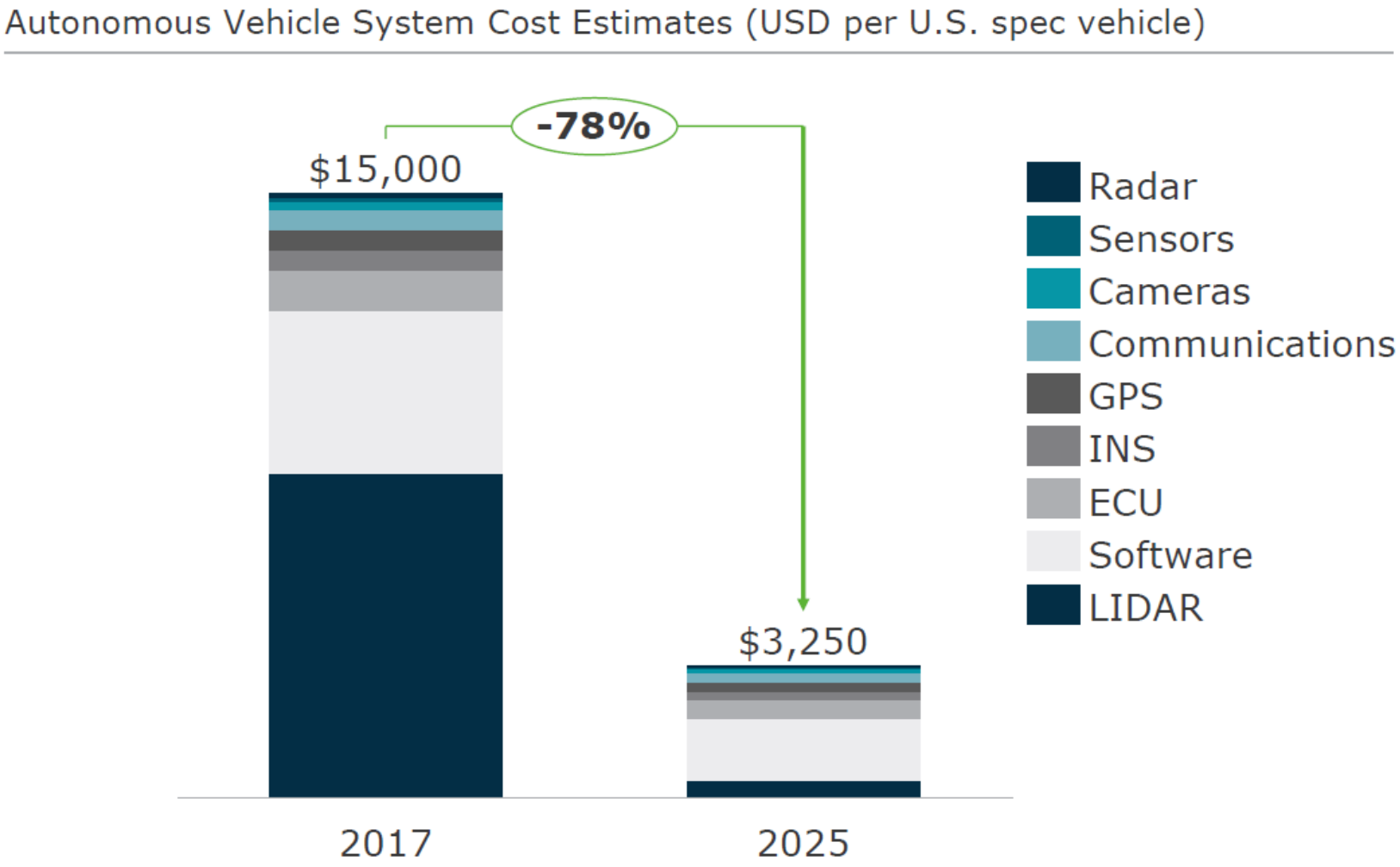
Projected Costs of a large BEV motor by Technology ($/kW)




Source: http://www.dbusiness.com/daily-news/Annual-2017/Report-As-Ridesharing-Increases-Auto-Companies-Need-Strategic-Partnerships/AlixPartners%20Automotive%20Outlook%202017_EMBARGOED%20TILL%201201%20AM%20ET%20JULY%2012%2C%202017.pdf

# technology cost

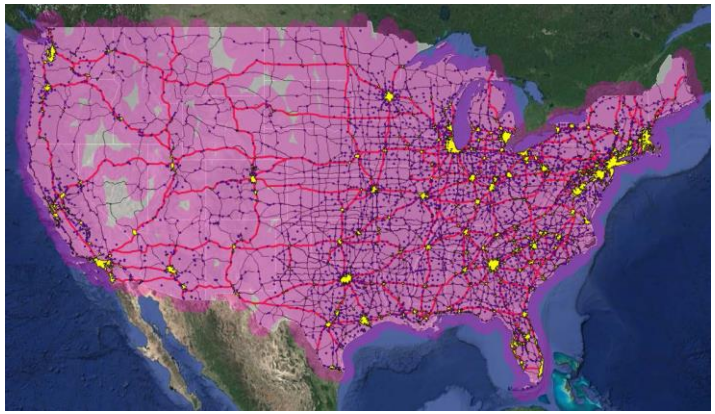
## Alix: Cost of AV systems should drop 78% by 2025

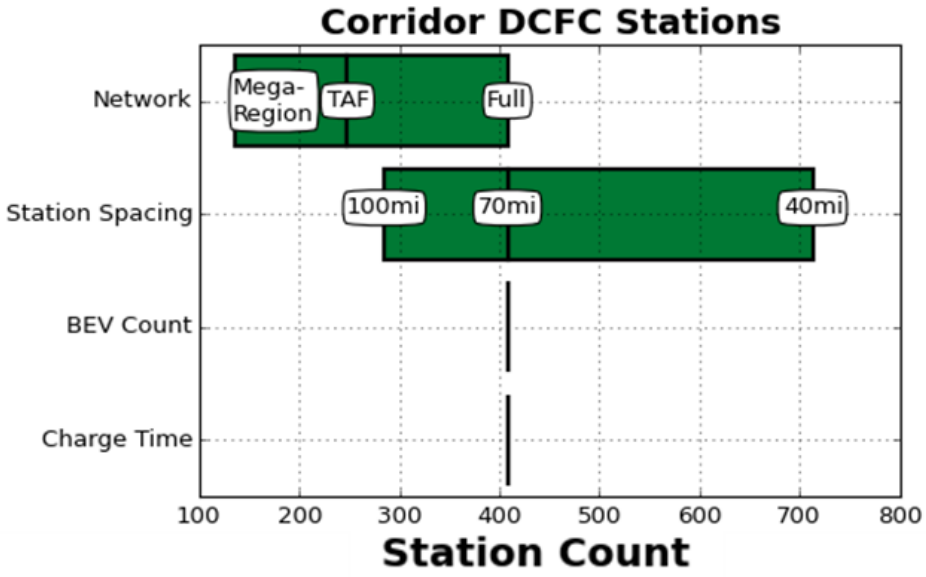


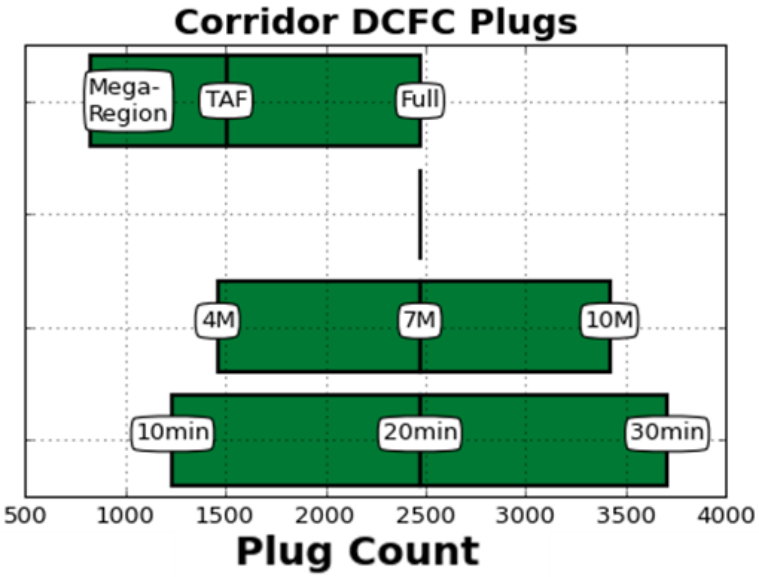

Source: http://www.dbusiness.com/daily-news/Annual-2017/Report-As-Ridesharing-Increases-Auto-Companies-Need-Strategic-Partnerships/AlixPartners%20Automotive%20Outlook%202017_EMBARGOED%20TILL%201201%20AM%20ET%20JULY%2012%2C%202017.pdf

# EV charging

## NREL: 400 corridor DCFC stations can cover the continental United States



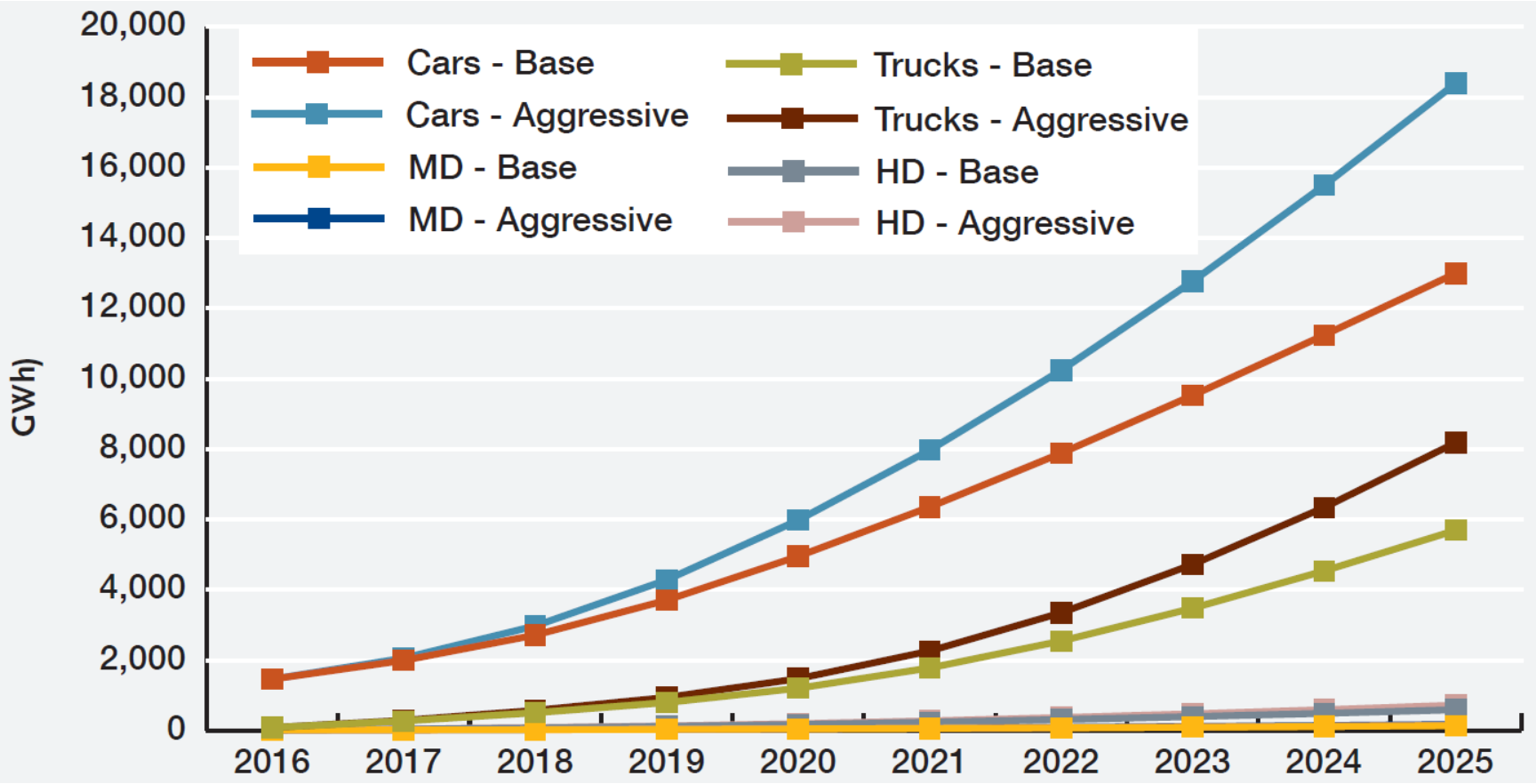



Source: https://www.nrel.gov/docs/fy17osti/69031.pdf

# EV charging

## Navigant/Fuels Institute: Electricity consumption is projected to grow 32-37% per year through 2025

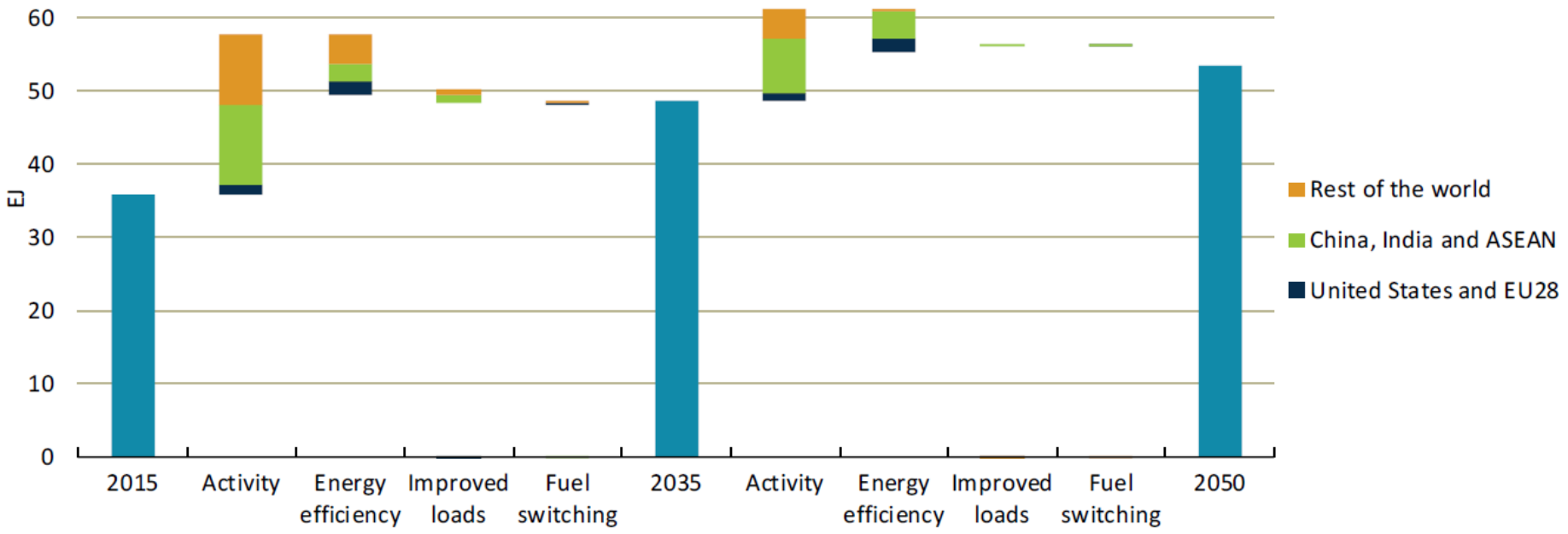



Source: http://www.fuelsinstitute.org/research.shtm

# HDV energy use

## IEA: Efficiency gains expected to fully counter increased demand for HDV through 2050 in developed countries, but not in developing countries

**Figure 30 • Decomposition of drivers of energy demand in the Reference Scenario**

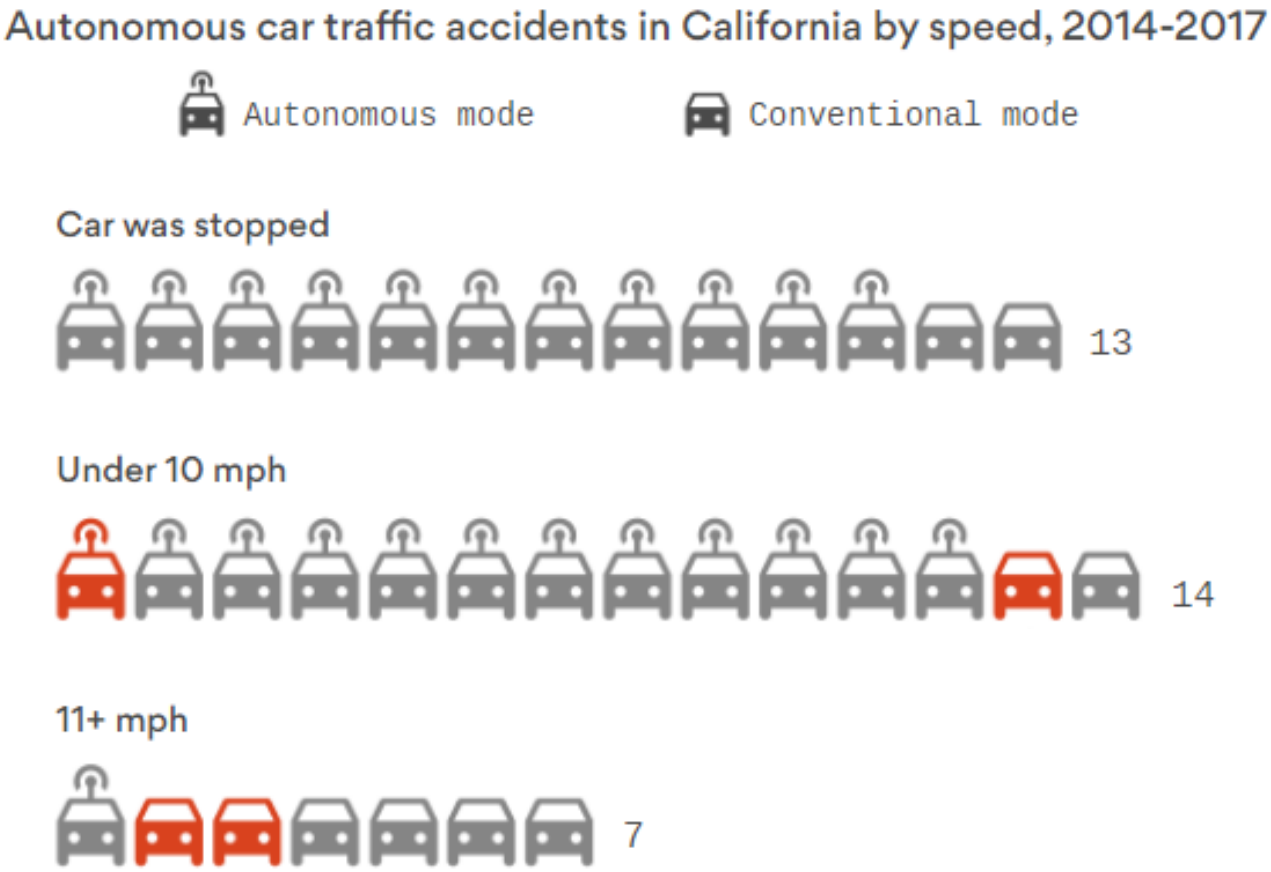



Source: IEA (2017a), Mobility Model, June 2017 version, database and simulation model, www.iea.org/etp/etpmodel/transport/.

Source: http://www.iea.org/publications/freepublications/publication/the-future-of-trucks---implications-for-energy-and-the-environment.html

# CAVs

## Axios: People have been at fault in majority of car accidents involving AVs in California since 2014



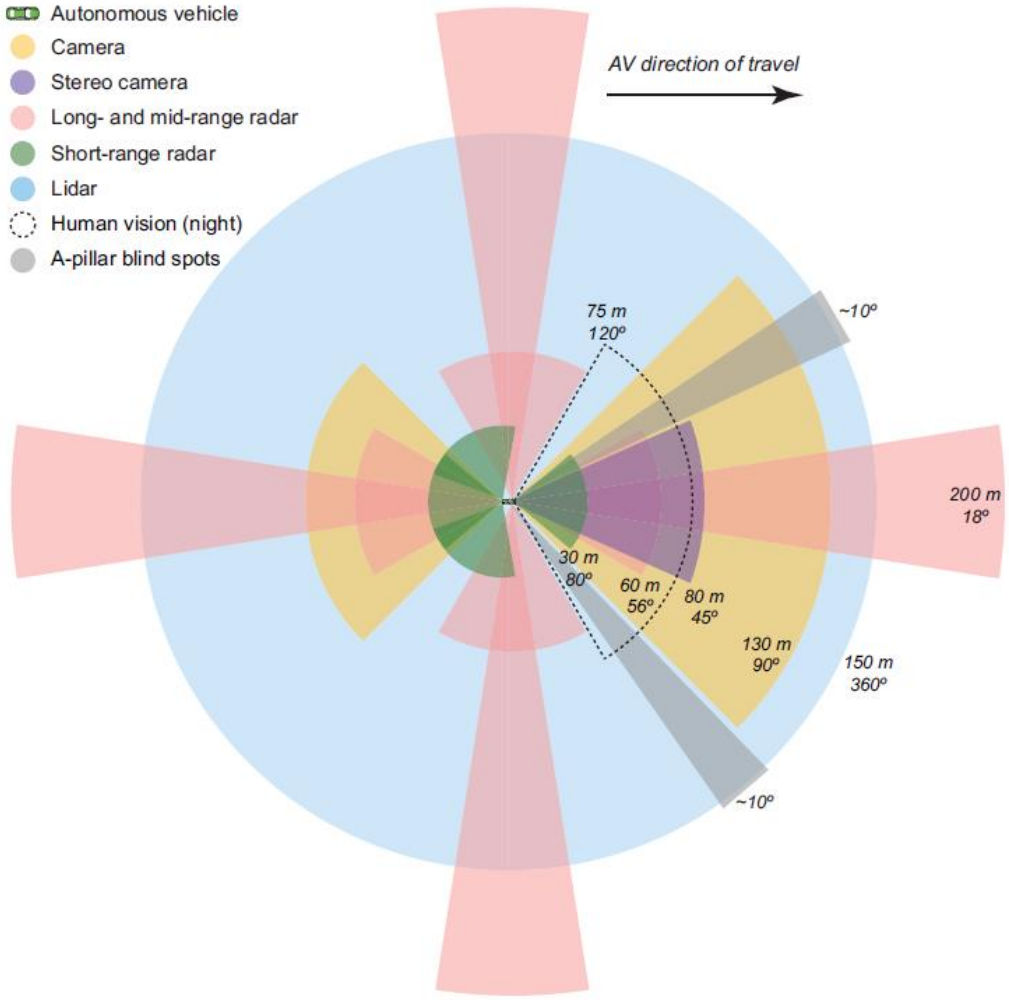

**Orange: Fault of AV-capable vehicle**

**Gray: Fault of conventional vehicle**

Source: https://www.axios.com/autonomous-car-traffic-accidents-2466289474.html

# CAVs

## UM: Sensors for automated and connected vehicles can supplement and improve upon human vision




Source: http://www.umich.edu/~umtriswt/PDF/SWT-2017-12_Abstract_English.pdf

## topics

energy markets

automotive markets

technologies studies

4 environmental studies

behavior & opinion surveys

policy & business studies

qar

# outline

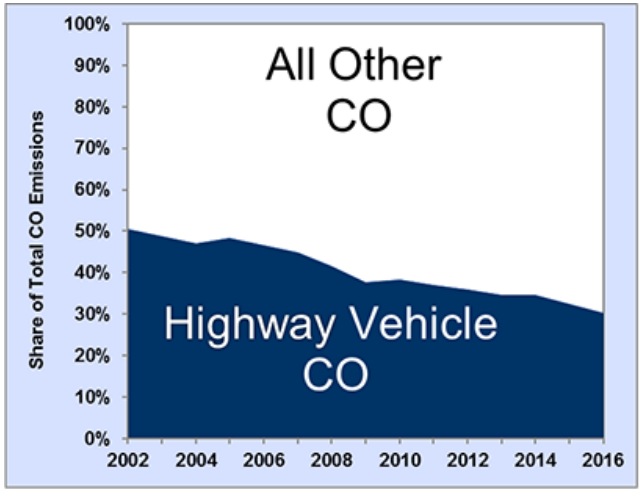
# 4 environmental studies

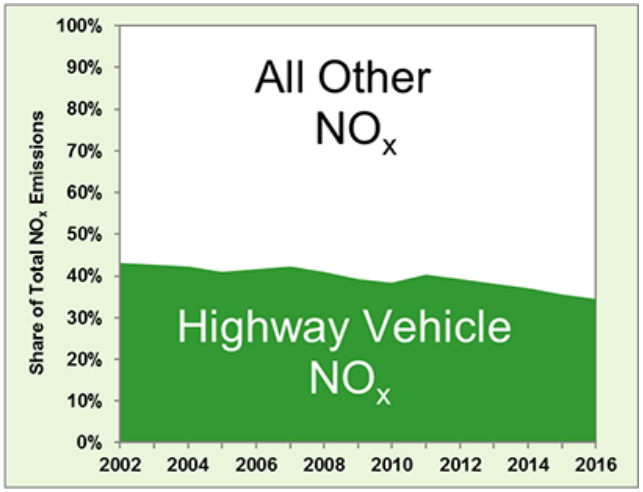
## emissions

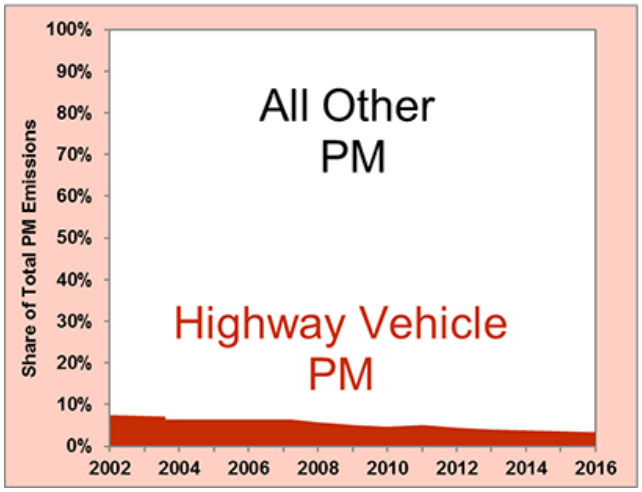
- FOTW: Highway vehicles are responsible for a declining share of pollutants
- FOTW: Despite rise in VMT, highway pollutants down 50% in 2016 from 2002
- Emissions Analytics: Cold engines emit more NOx than warmer engines

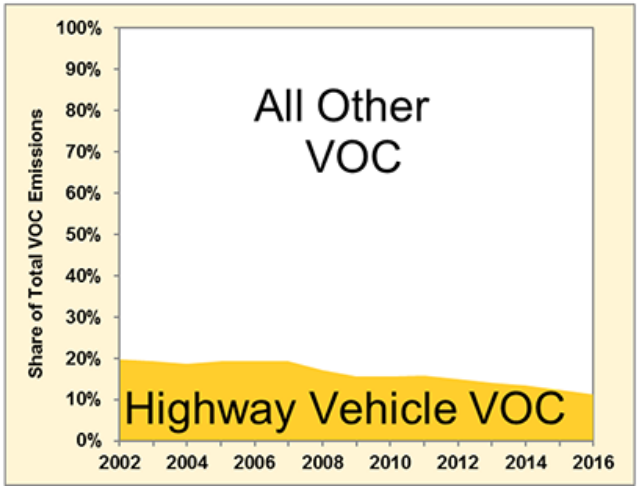
# emissions

## FOTW: Highway vehicles are responsible for a declining share of pollutants



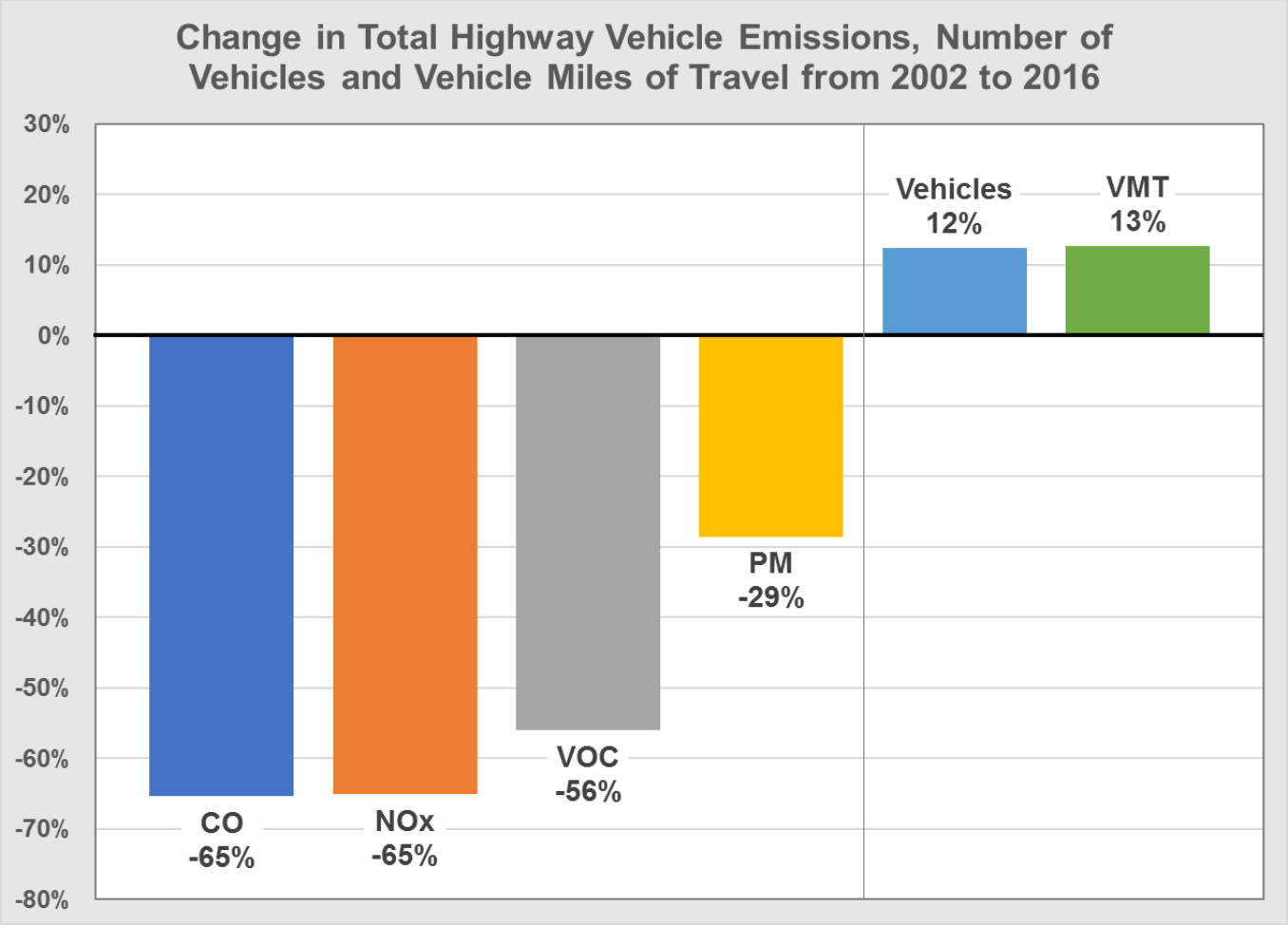




Source: https://energy.gov/eere/vehicles/articles/fact-998-october-9-2017-highway-vehicles-responsible-declining-share

# emissions

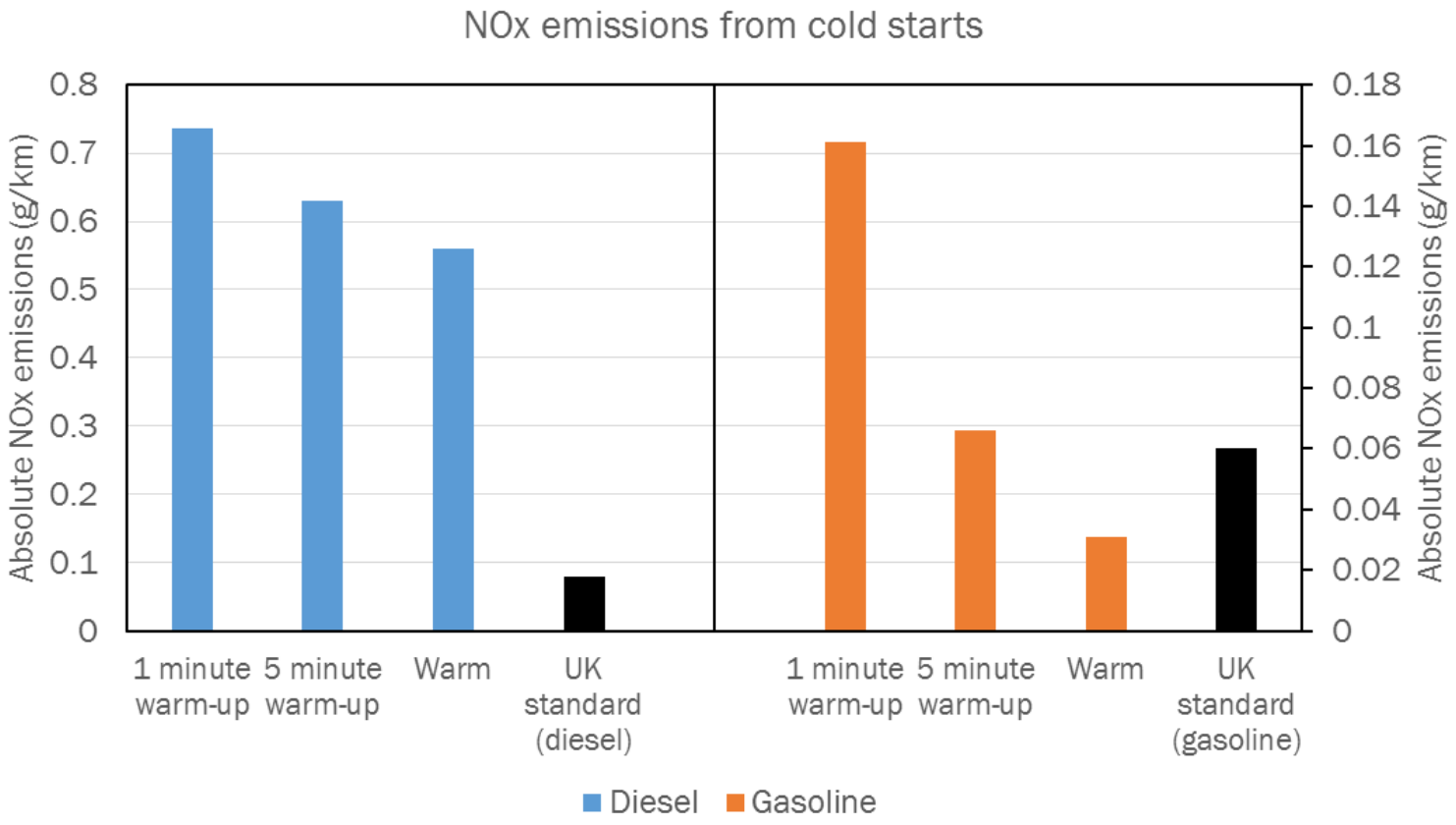
## FOTW: Despite rise in VMT, highway pollutants down 50% in 2016 from 2002




Source: https://energy.gov/eere/vehicles/articles/fact-999-october-16-2017-despite-rise-vehicle-miles-travel-highway-pollutants

# emissions

## Emissions Analytics: NOx emissions are higher with cold engines; diesel engines (on-road) do not meet European standards




Source: http://usa.equaindex.com/why-cold-starts-could-freeze-air-pollution-improvements/

# topics

energy markets

automotive markets

technologies studies

environmental studies

5 behavior & opinion surveys

policy & business studies

qar

outline

# 5 behavior & opinion surveys

## CAVs

> CityLab/NBC4: “Self-driving” vehicle testing public acceptance of CAVs
> Pew: Americans expect driverless cars by 2060; majority still not ready

## Commuting patterns

> ACS via Bloomberg: People in different income levels have different commuting patterns
> Pew via Curbed: Number of “Super-commuters” grew by nearly 25%

## Vehicle miles traveled

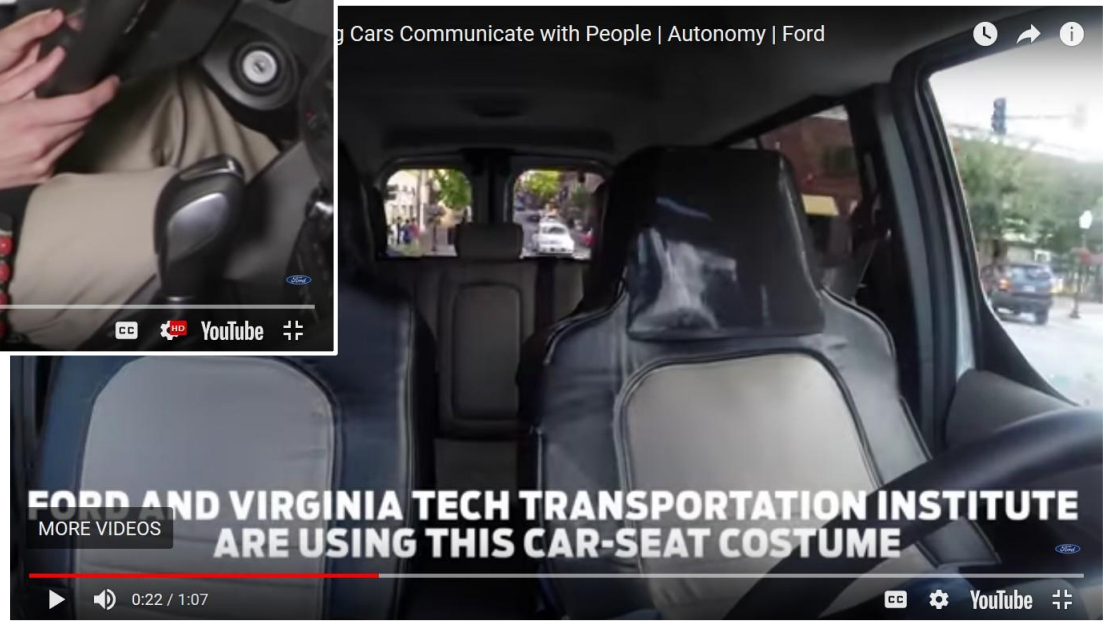
> AASHTO: Generational and economic factors are both responsible for decrease in driving by Millennials

## traffic

> Citylab: Path of solar eclipse visible by Google Maps traffic data

# CAVs

## CityLab/NBC4: "Self-driving" vehicle testing public acceptance of CAVs in Arlington

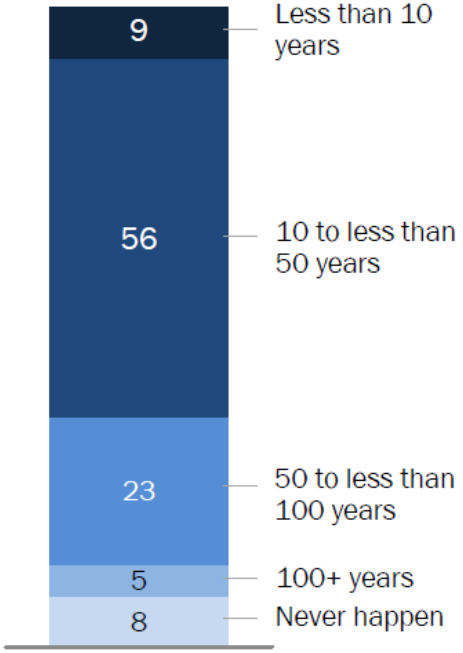

Sources: https://www.citylab.com/transportation/2017/09/how-to-talk-robot-car/539814/ and http://www.nbcwashington.com/news/local/Driver-Dressed-Like-a-Seat-Spotted-Inside-Driverless-Van-439041863.html and https://www.citylab.com/transportation/2017/08/heres-the-real-science-behind-that-fake-driverless-car/536268/

# CAVs

## Pew: Americans expect driverless cars by 2060; majority still not ready to ride in AVs

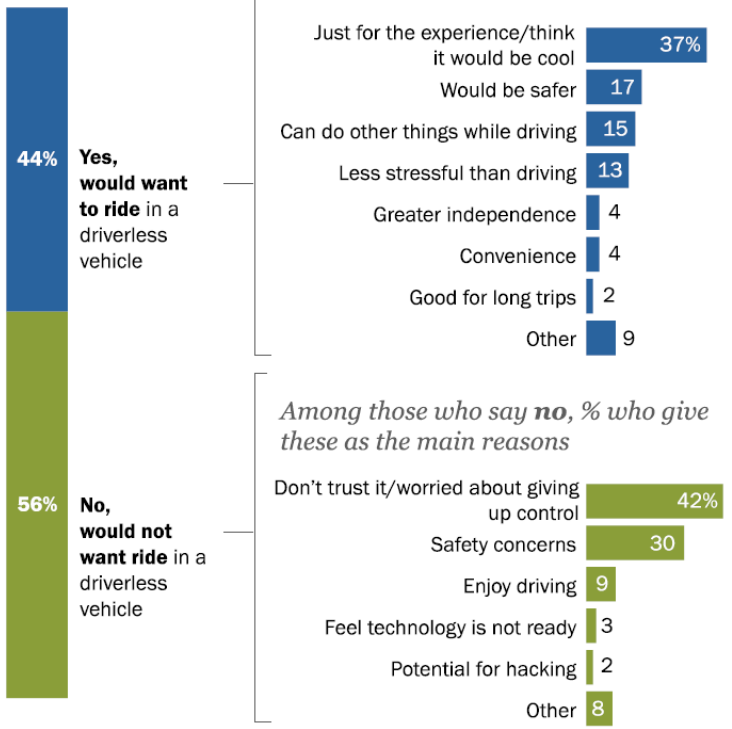
**Roughly two-thirds of Americans expect most cars to be driverless in next half century**

*% of U.S. adults who say it will take ___ for most vehicles on the road to be driverless*




**Slight majority of Americans would not want to ride in a driverless vehicle if given the chance; safety concerns, lack of trust lead their list of concerns**

*% of U.S. adults who say they would/would not want to ride in a driverless vehicle*



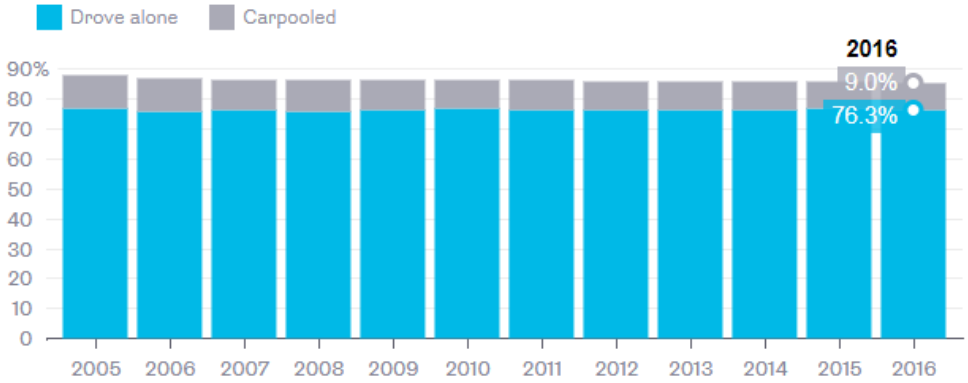

Source: http://www.pewinternet.org/2017/10/04/automation-in-everyday-life/

# commuting patterns

## ACS via Bloomberg: People in different income levels have different commuting patterns

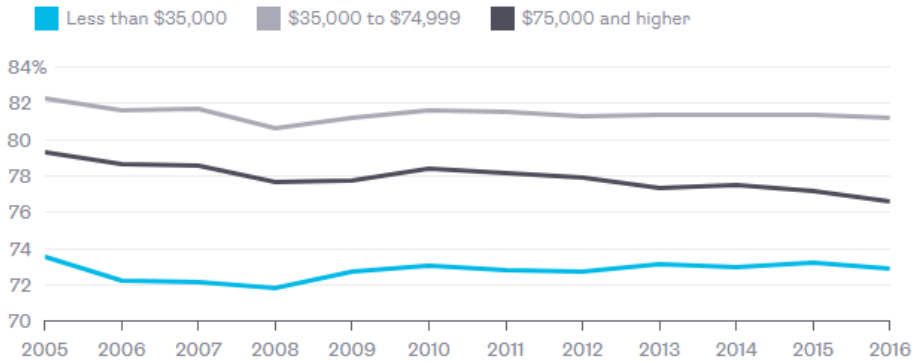
### Driving to Work

Percentage of U.S. workers who commuted by car, truck or van



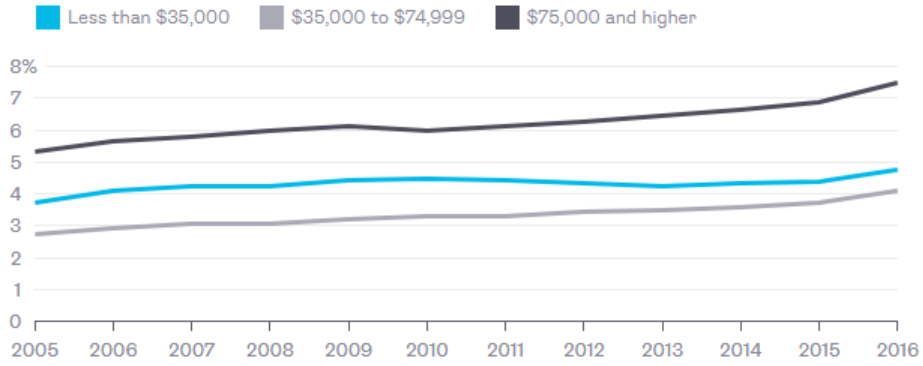

### Who Drives to Work

Percentage driving alone to work, by annual earnings



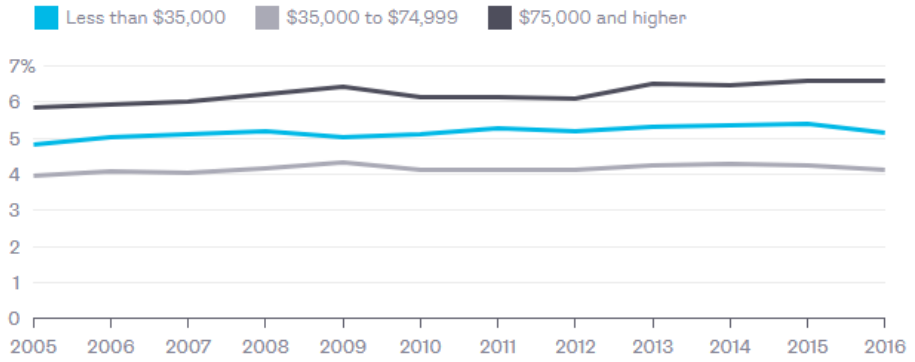

### The Shortest Commute

Percentage working from home, by annual earnings




### Who Rides the Bus and Train

Percentage commuting via public transportation, by annual earnings



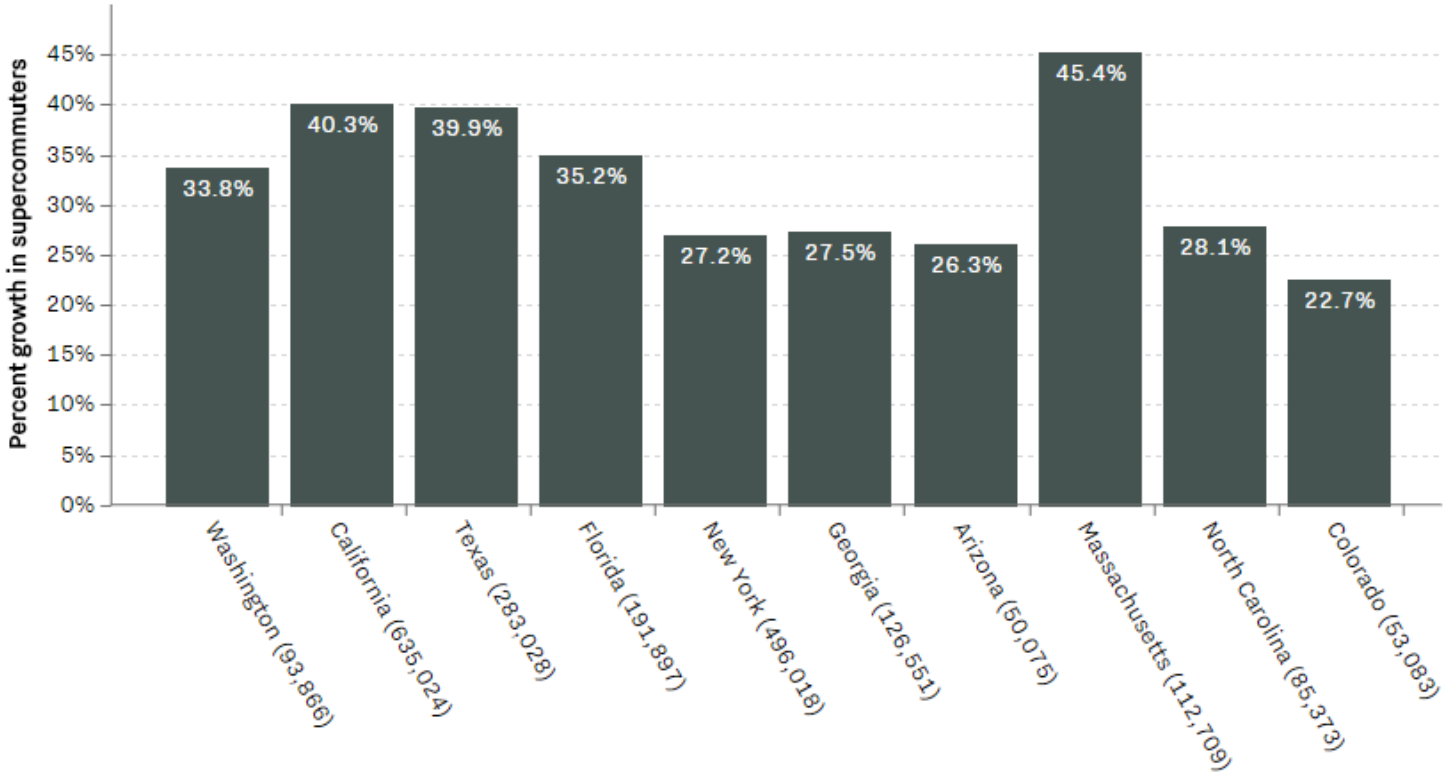

Source: https://www.bloomberg.com/view/articles/2017-09-18/not-driving-to-work-is-the-hot-new-high-end-job-perk

# commuting patterns

## Pew via Curbed: Number of "Super-commuters" grew by nearly 25% between 2010 and 2015

### Spike in Supercommuters

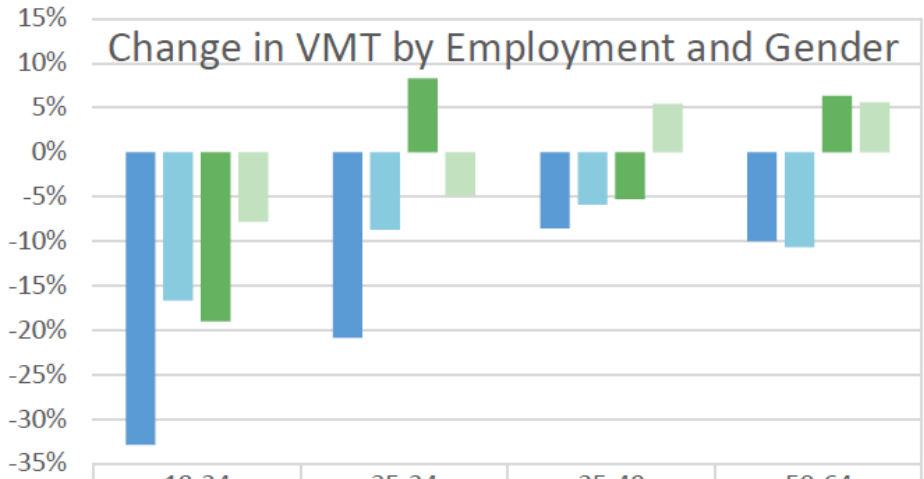
Between 2010 and 2015, the number of American supercommuters—those with commutes of 90 minutes or more—has skyrocketed. The numbers in parenthesis are the total number of supercommuters in each state.



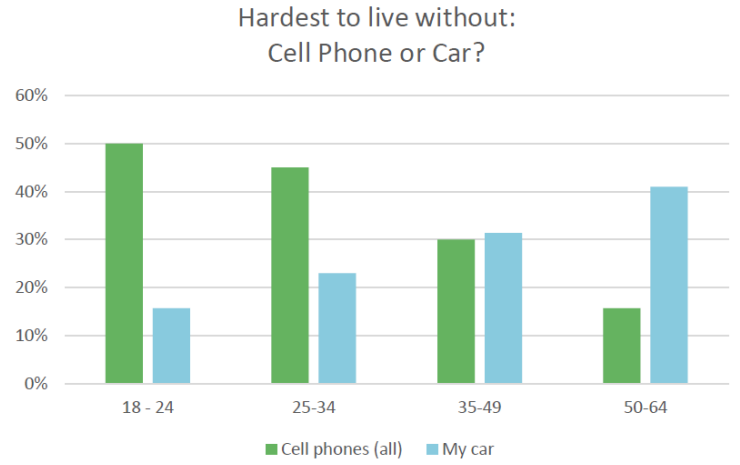

Source: https://www.curbed.com/2017/6/20/15834514/rent-transportation-commute-affordable-housing

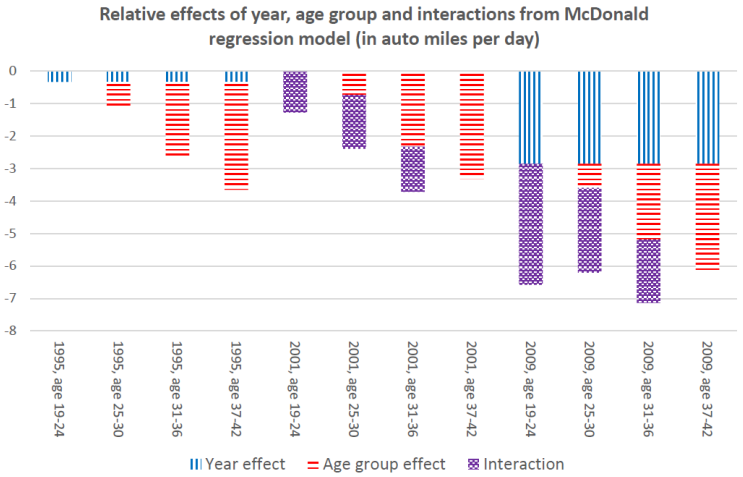
# vehicle miles traveled

## AASHTO: Generational and economic factors are *both* responsible for decrease in driving by Millennials




| | 18-24 | 25-34 | 35-49 | 50-64 |
|---|---|---|---|---|
| Male Unemployed | -33% | -21% | -9% | -10% |
| Male Employed | -17% | -9% | -6% | -11% |
| Female Unemployed | -19% | 8% | -5% | 6% |
| Female Employed | -8% | -5% | 5% | 6% |




Source: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36(132)_FR.pdf

# traffic

## Citylab: Path of solar eclipse visible by Google Maps traffic data


Source: https://www.citylab.com/environment/2017/08/google-maps-traffic-data-mirrors-the-path-of-the-eclipse/537534/

# topics

energy markets

automotive markets

technologies studies

environmental studies

behavior & opinion surveys

6 policy & business studies

qar

outline

# 6 policy & business studies

## HOV policy

> Harvard/MIT: End of HOV policies in Jakarta increased delays on both formerly restricted and unrestricted roads

## freight

> FOTW: Trucks and air larger fraction of freight rail and pipeline move goods
> FOTW: Motor vehicles second most valuable commodity shipped in US

## EV supply chain

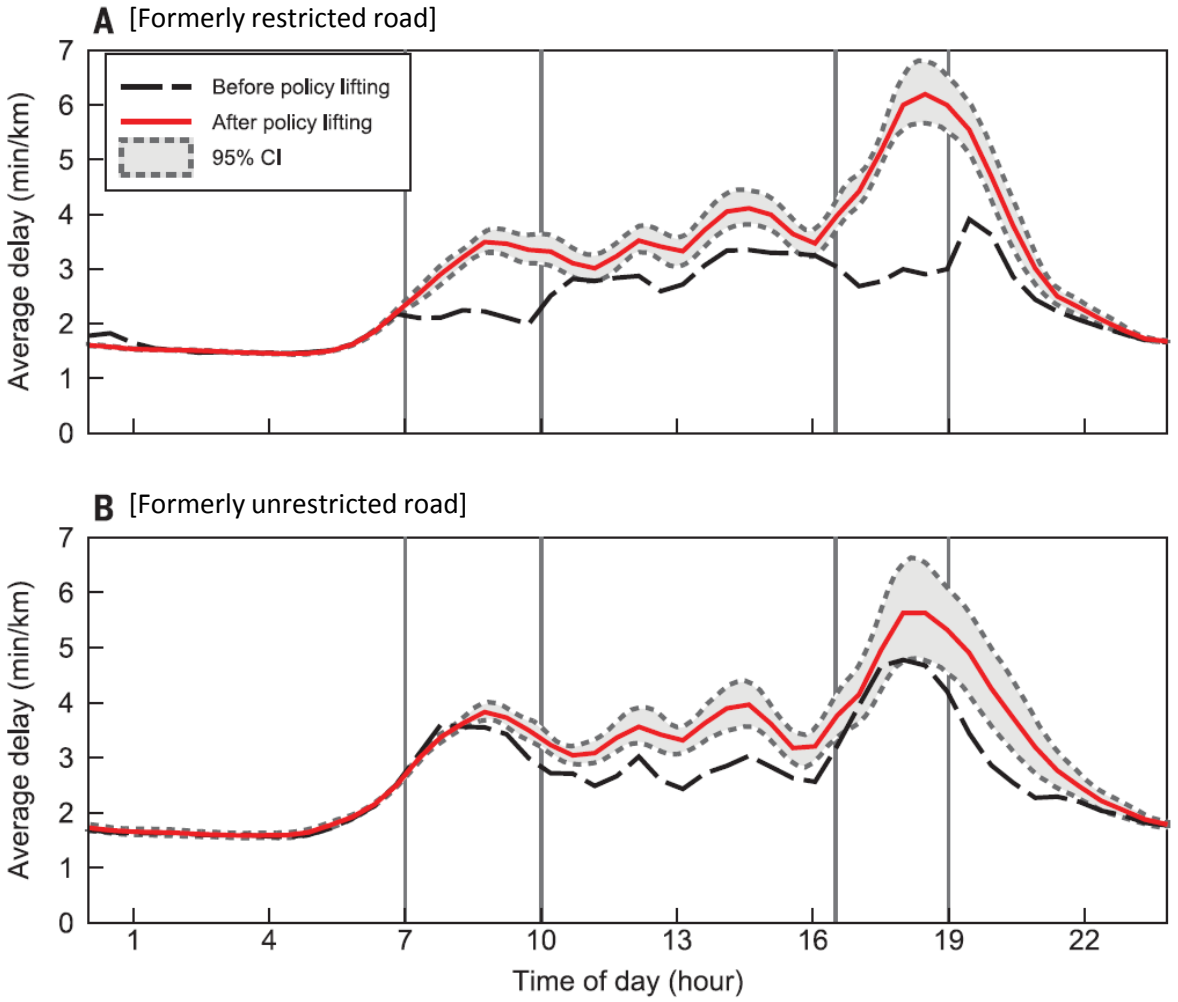
> Lux, Cairns, Economist, Quartz, Reuters, VisualCapitalist: Rapid growth expected in PEVs, could lead to massive increases in commodity usage

## employment

> Pew: Most American adults are worried about future due to automation

# HOV policy

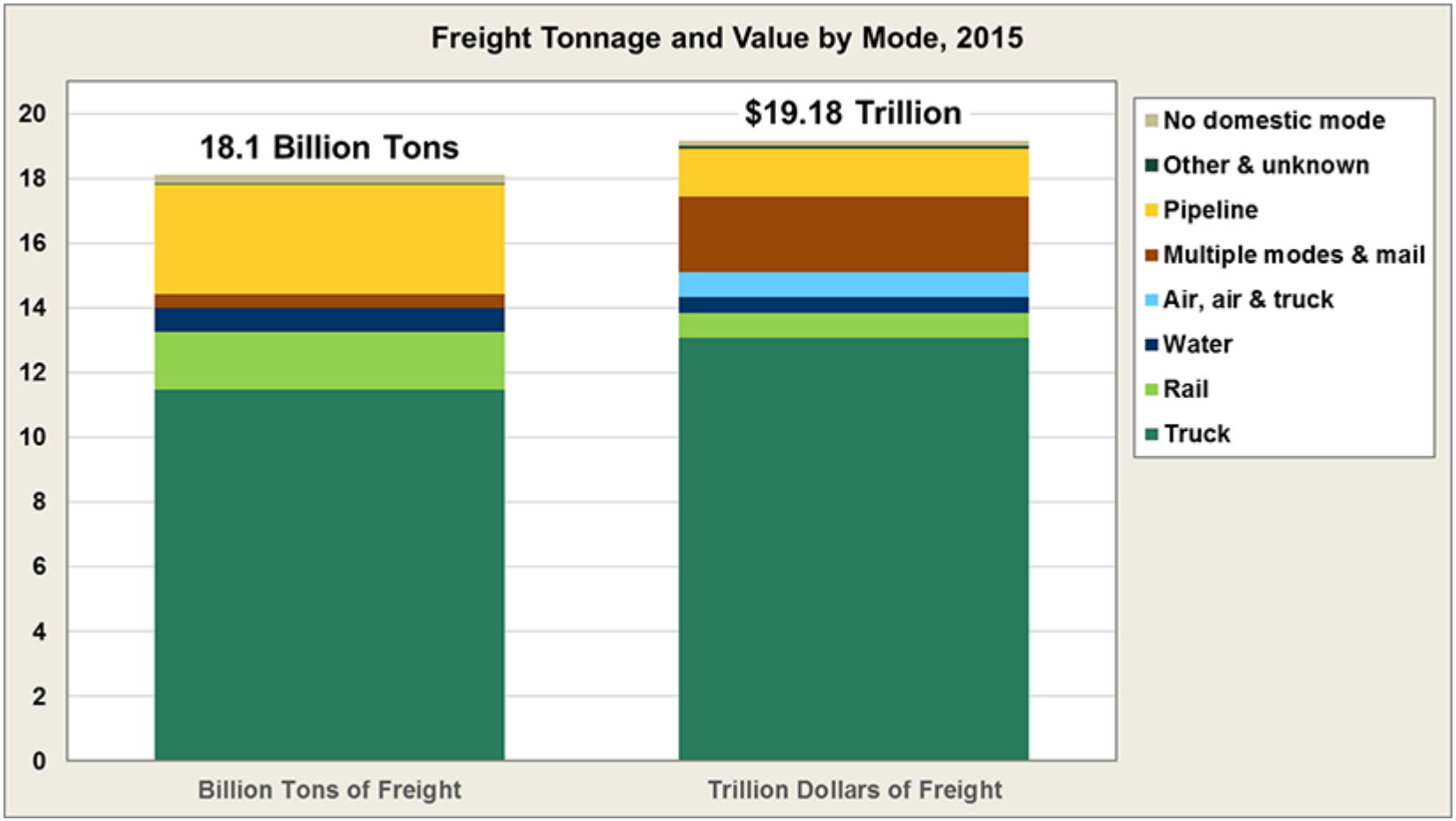
## Harvard/MIT: End of HOV policies in Jakarta increased delays on formerly restricted and unrestricted roads




Source: http://science.sciencemag.org/content/357/6346/89

# freight

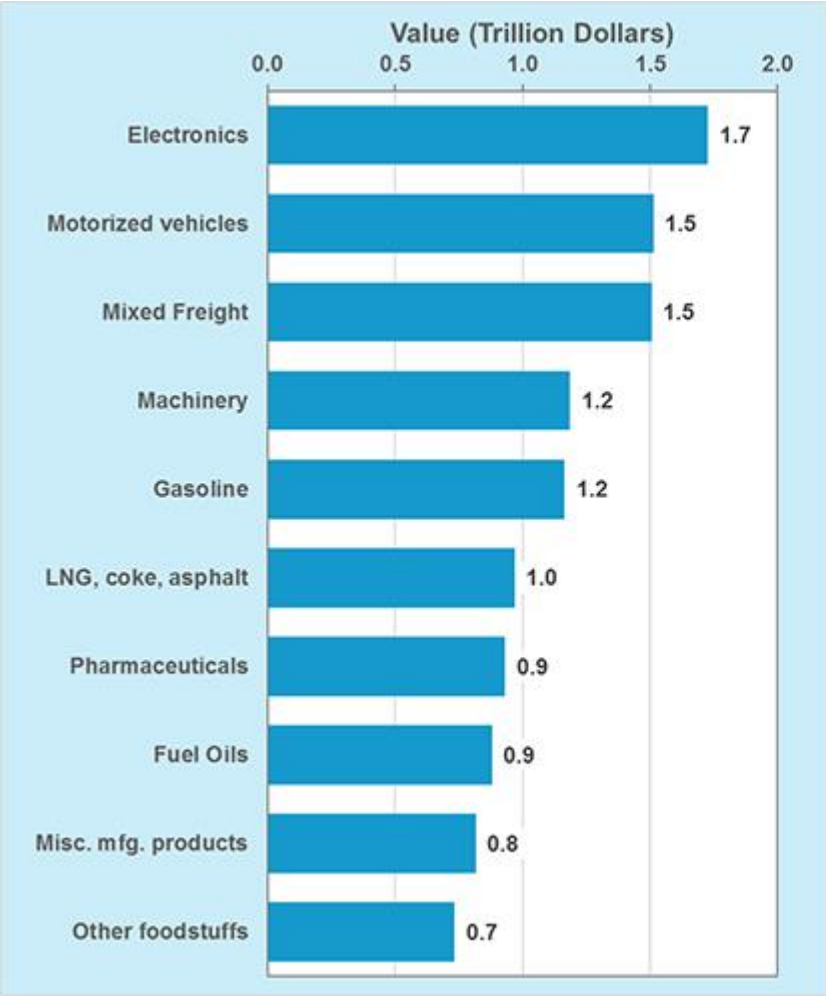
## FOTW: Trucks and air take up a larger fraction of freight by value; rail and pipeline move heavier goods

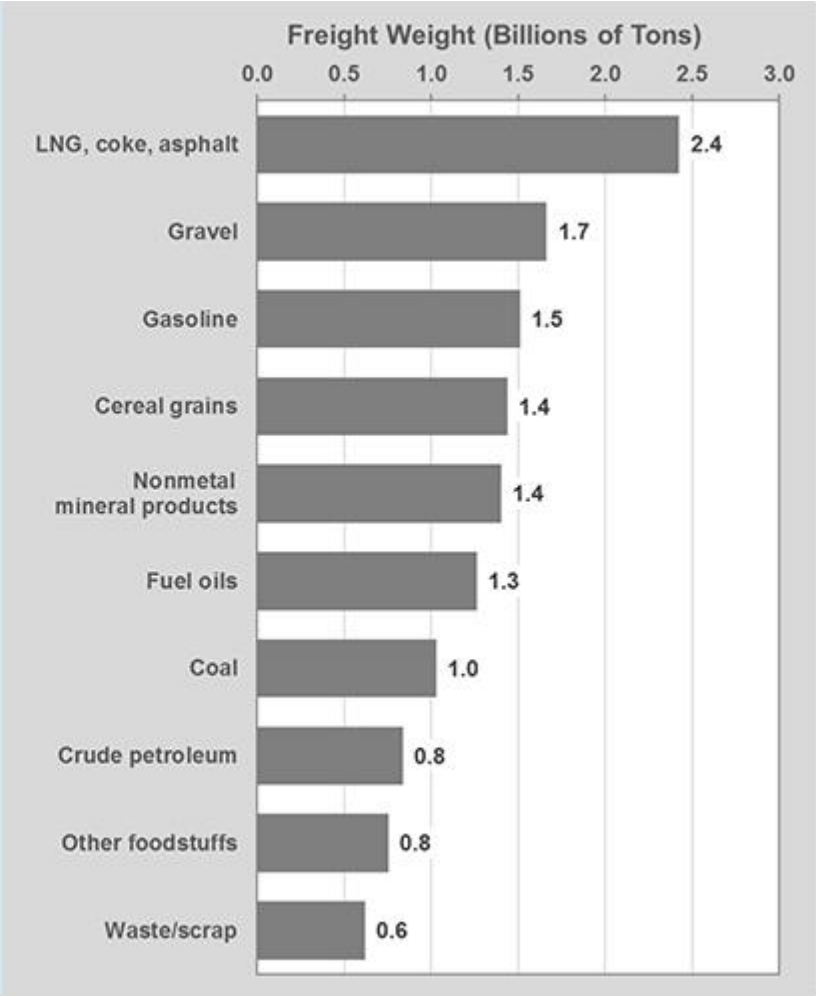



Source: https://energy.gov/eere/vehicles/articles/fact-991-august-21-2017-mode-transportation-freight-tonnage-and-freight-value

# freight

## FOTW: Motor vehicles are the second most valuable commodity shipped in the United States

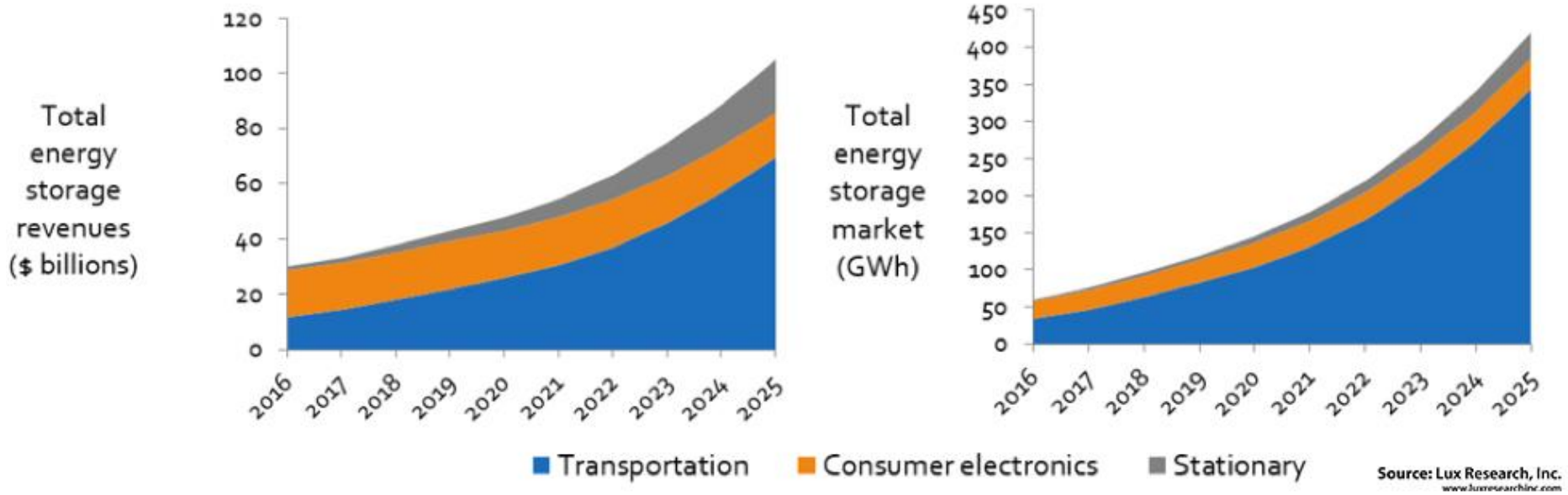



Source: https://energy.gov/eere/vehicles/articles/fact-992-august-28-2017-motor-vehicles-are-one-most-valuable-commodities

# EV supply chain

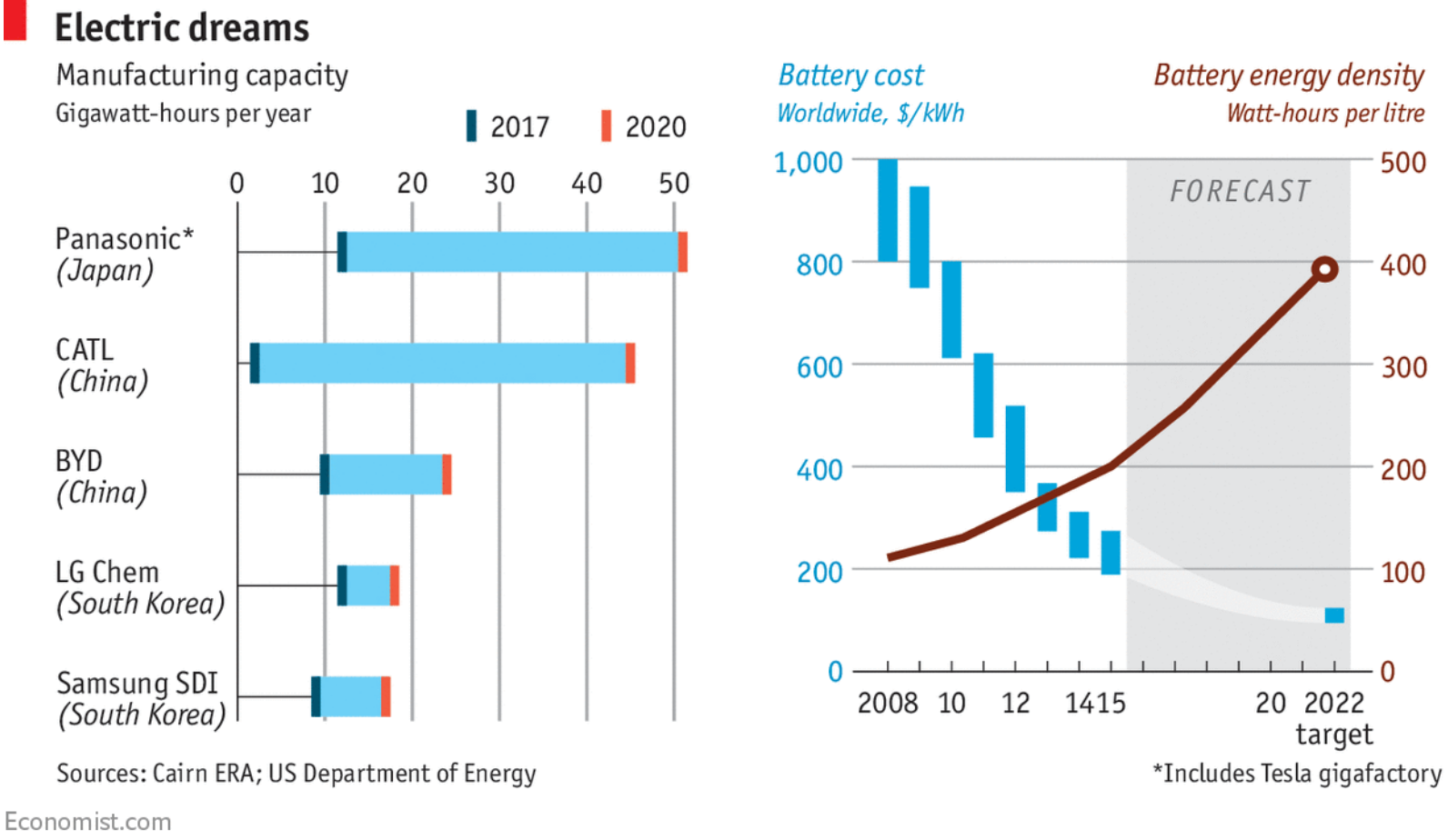
## Lux: Transportation will overtake consumer electronics as the largest market for energy storage by 2018




Source: http://blog.luxresearchinc.com/blog/2017/07/transportation-and-stationary-energy-storage-will-overtake-consumer-electronics-as-the-largest-markets-for-energy-storage-by-2018/

# EV supply chain

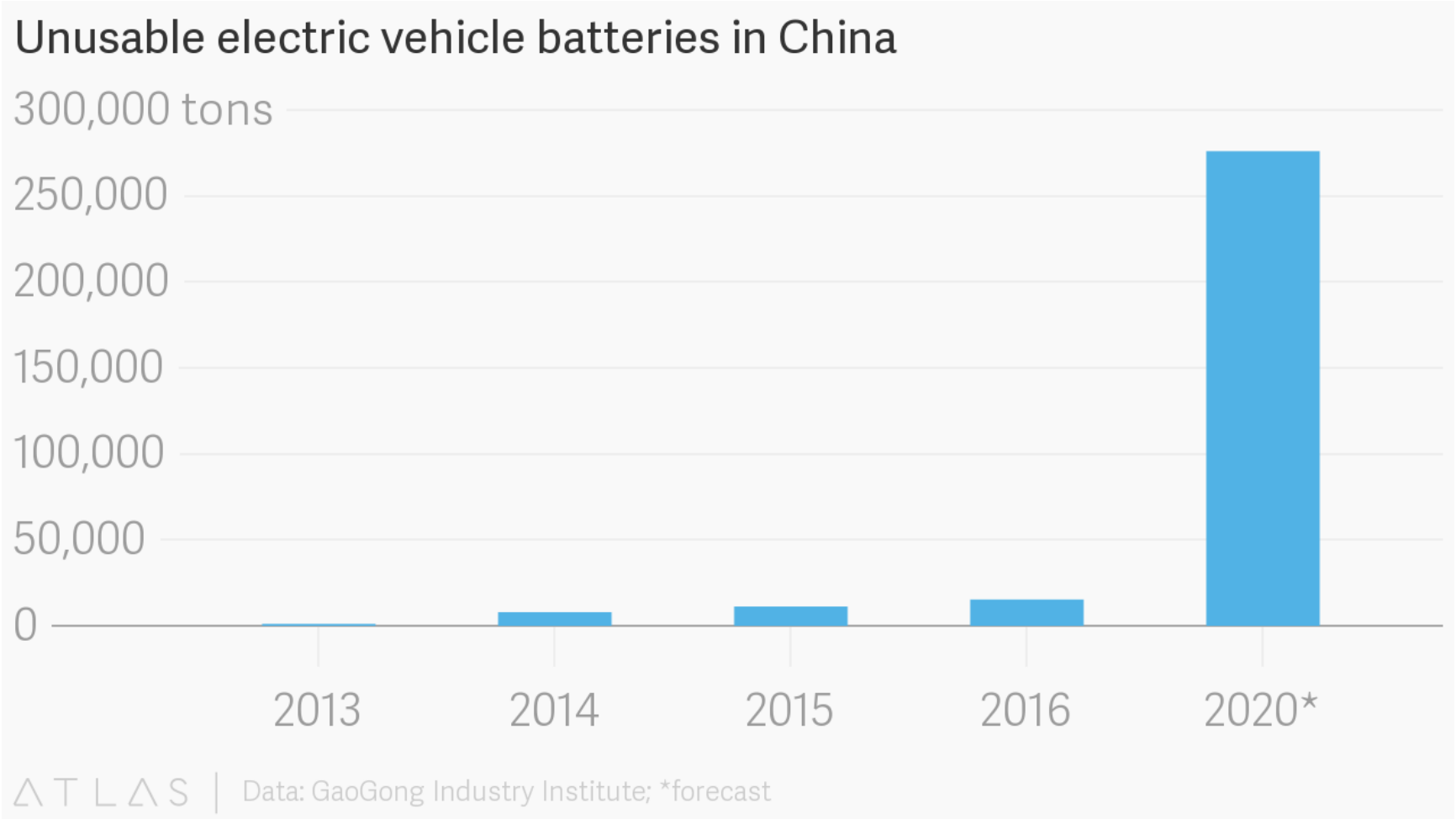
## Cairns via Economist: Battery production expected to grow rapidly for major producers by 2020




Source: https://www.economist.com/blogs/graphicdetail/2017/08/daily-chart-8

# EV supply chain

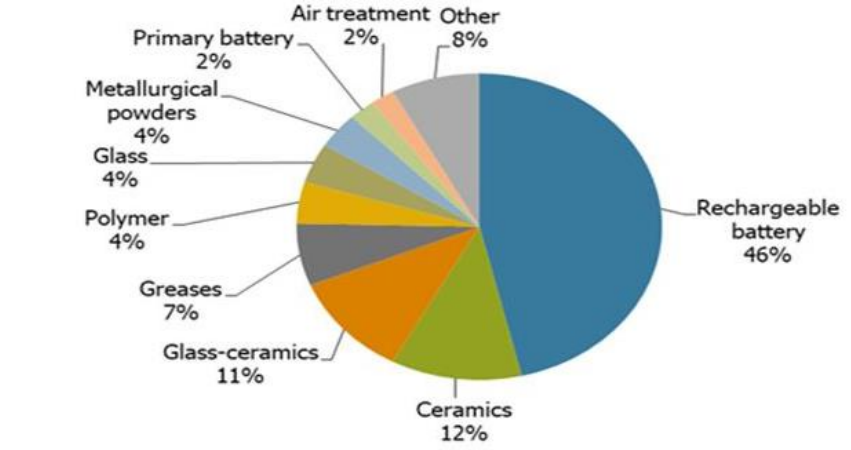
## Quartz: Over 250,000 tons of batteries (mostly LFP) due to be scrapped by 2020

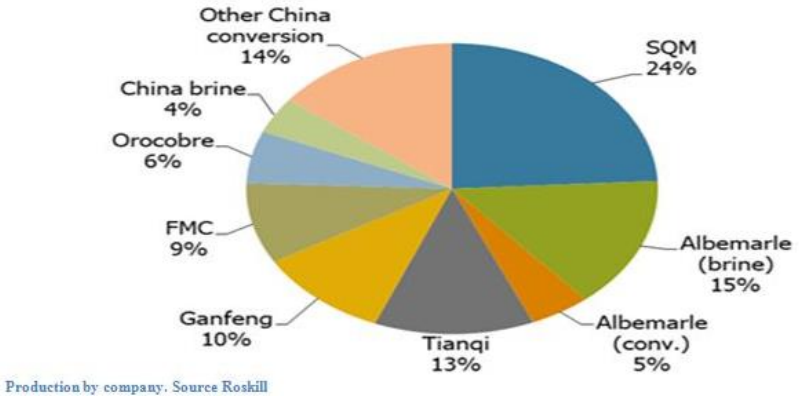



Source: https://qz.com/1088195/chinas-booming-electric-vehicle-market-is-about-to-run-into-a-mountain-of-battery-waste/

# EV supply chain

## Reuters: Lithium prices driven higher by use in batteries; 75% of production comes from 5 companies

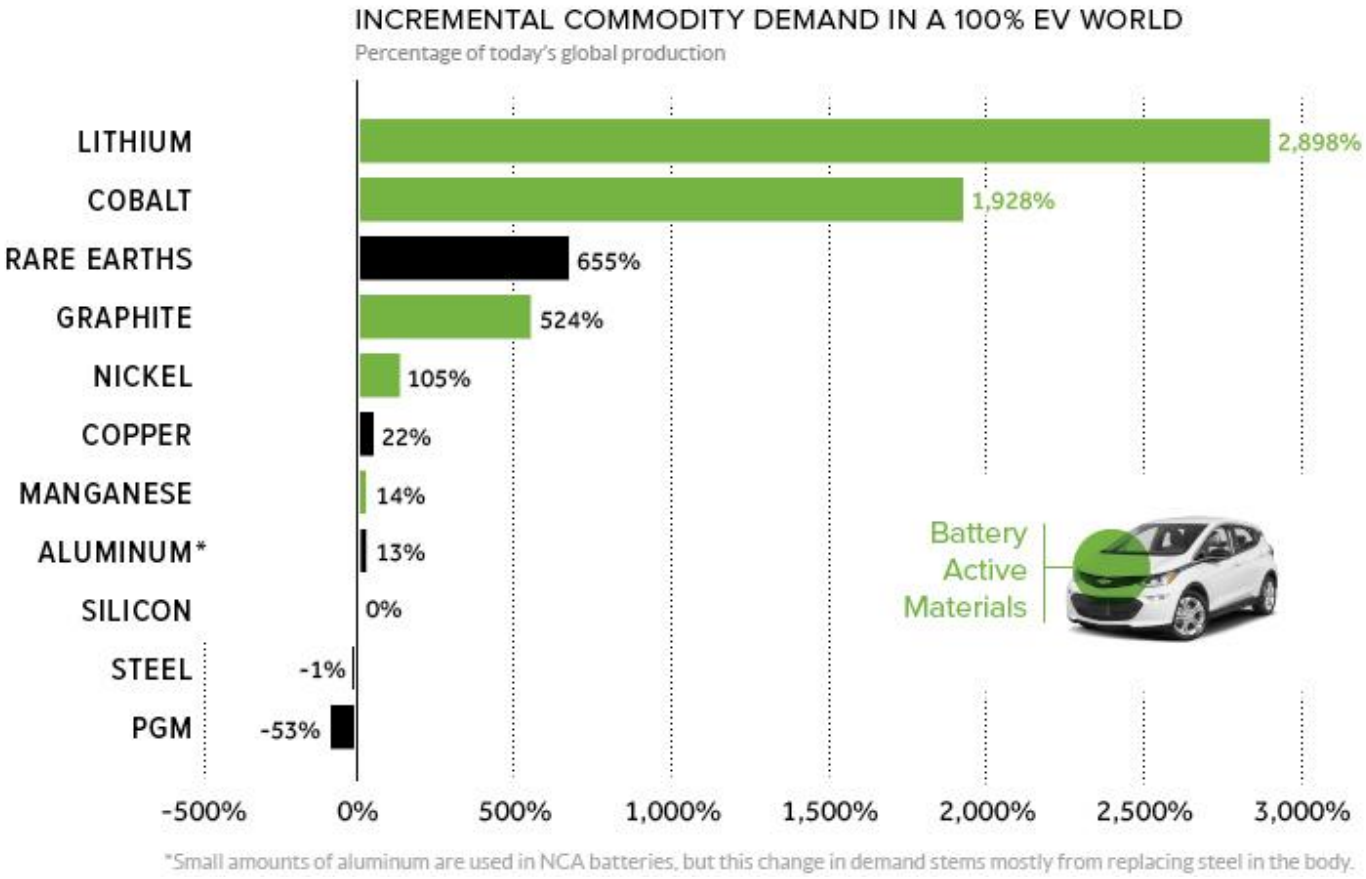




Source: https://www.reuters.com/article/us-lithium-processing-evs/lithium-processors-prepare-to-meet-demand-in-era-of-electric-car-idUSKBN1AN1DX

# EV supply chain

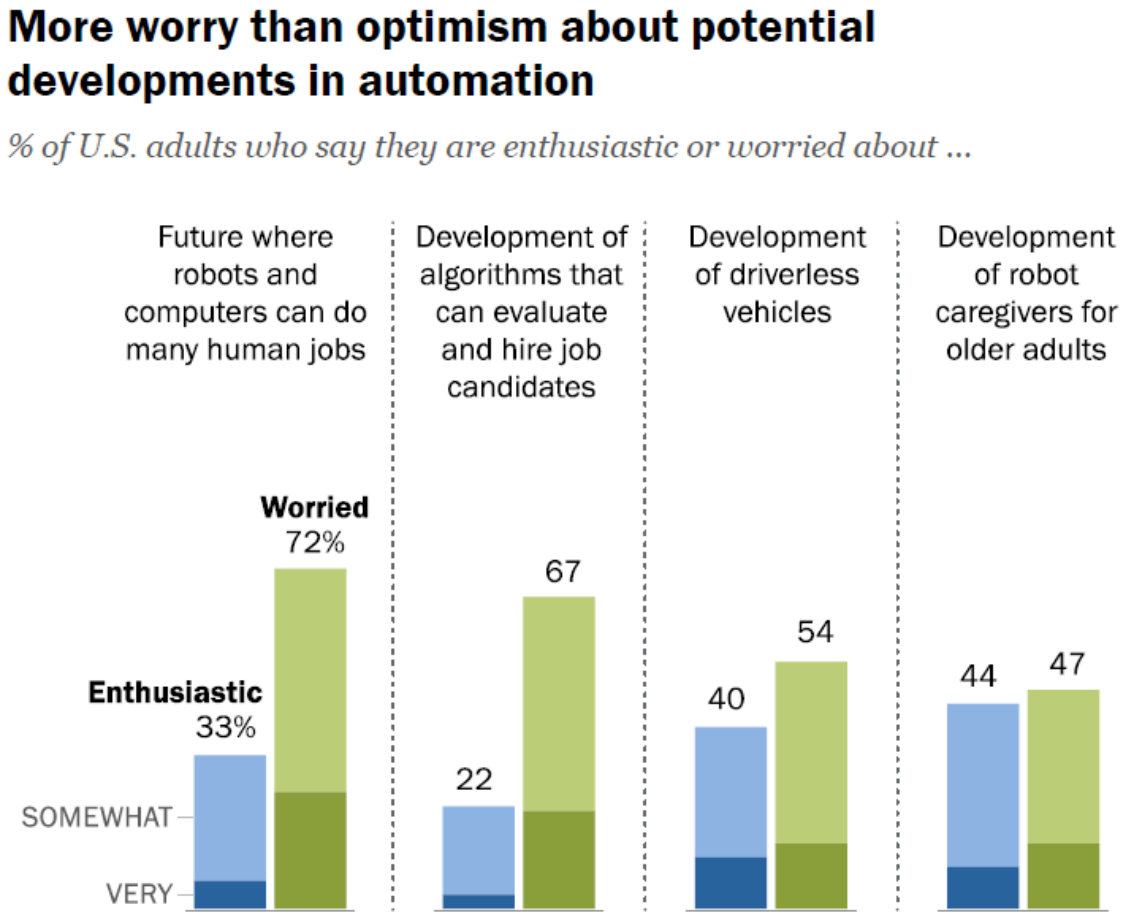
## VisualCapitalist: 100% EVs (Chevy Bolt NCA design) would lead to 30x increase in lithium demand, 20x increase in cobalt demand




Source: http://www.visualcapitalist.com/massive-impact-evs-commodities/

# employment

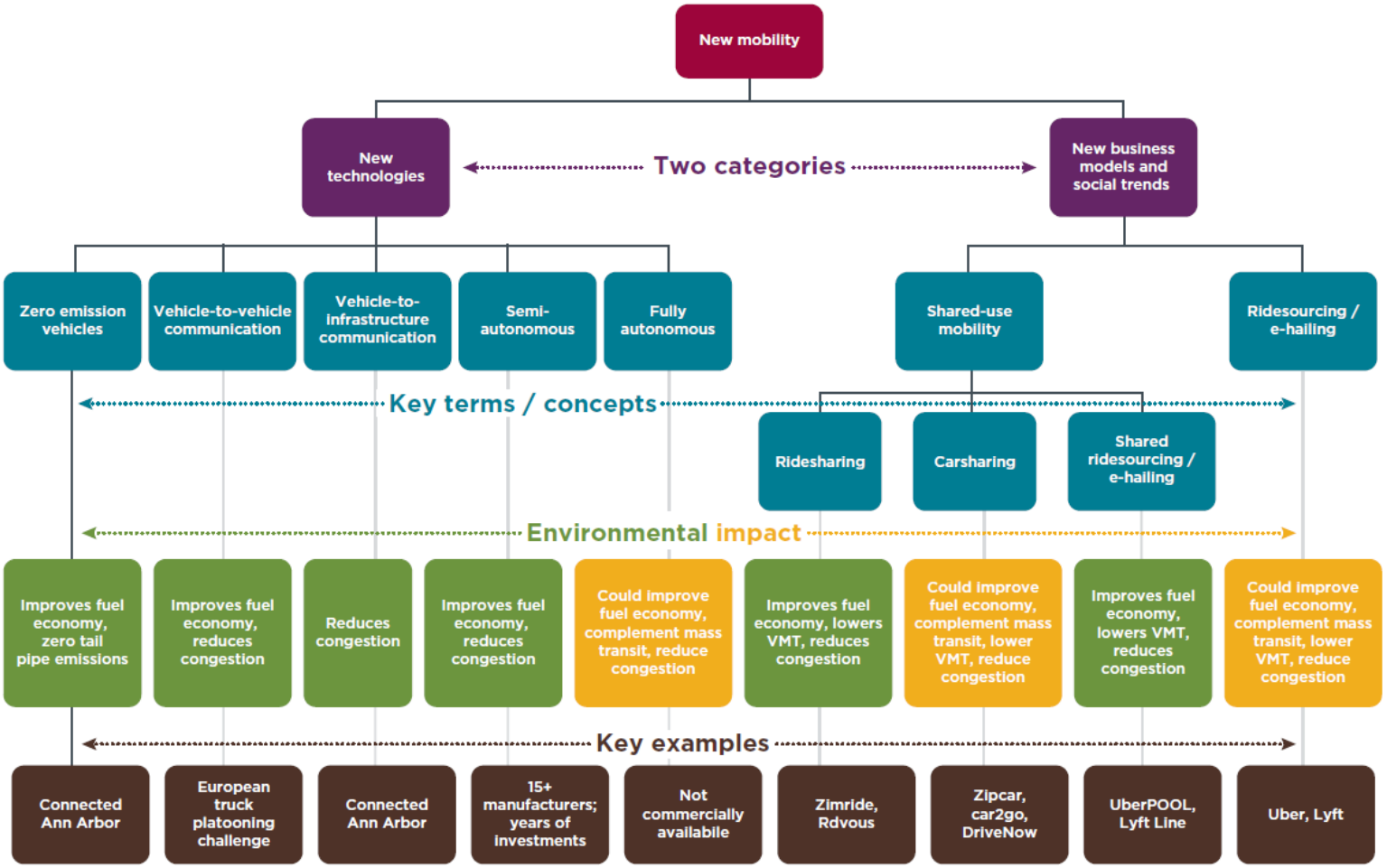
## Pew: Most American adults are worried about future with automated labor and about AVs




Source: http://www.pewinternet.org/2017/10/04/automation-in-everyday-life/

# future of mobility

## ICCT: Taxonomy for new mobility landscape spans technologies and new business models/social trends




Source: http://www.theicct.org/new-mobility-tech-and-policy-landscape-2017

# tools

## ANL: Updates of GREET, AFLEET, and VISION

AFLEET — short for Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool — is a free publicly available tool that calculates and compares the costs and environmental benefits of a broad range of alternative fuel technologies.

GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis.

The VISION model has been developed to provide estimates of the potential energy use, oil use and carbon emission impacts of advanced light- and heavy-duty vehicle technologies and alternative fuels through the year 2100.

Sources: http://greet.es.anl.gov/ and https://greet.es.anl.gov/afleet and http://www.anl.gov/energy-systems/project/vision-model

# summary observations

| | |
|---|---|
| **energy** | Transportation responsible for 70% of petroleum usage in U.S.; gasoline prices stable since 2015 |
| **automotive** | LDV sales prices in U.S. at record high; PEV market projected to grow rapidly in U.S. and worldwide |
| **tech/enviro** | 400 DCFC stations can cover the U.S.; costs of advanced vehicle technologies expected to decrease; highway vehicles responsible for a declining share of pollutants |
| **opinion/policy** | HOV policies can reduce congestion and delays; trucks and planes used to ship valuable goods; rapid growth in PEVs could lead to massive increases in commodity usage |

**17.3**
**3Q 2017**

**qar**
**summary**